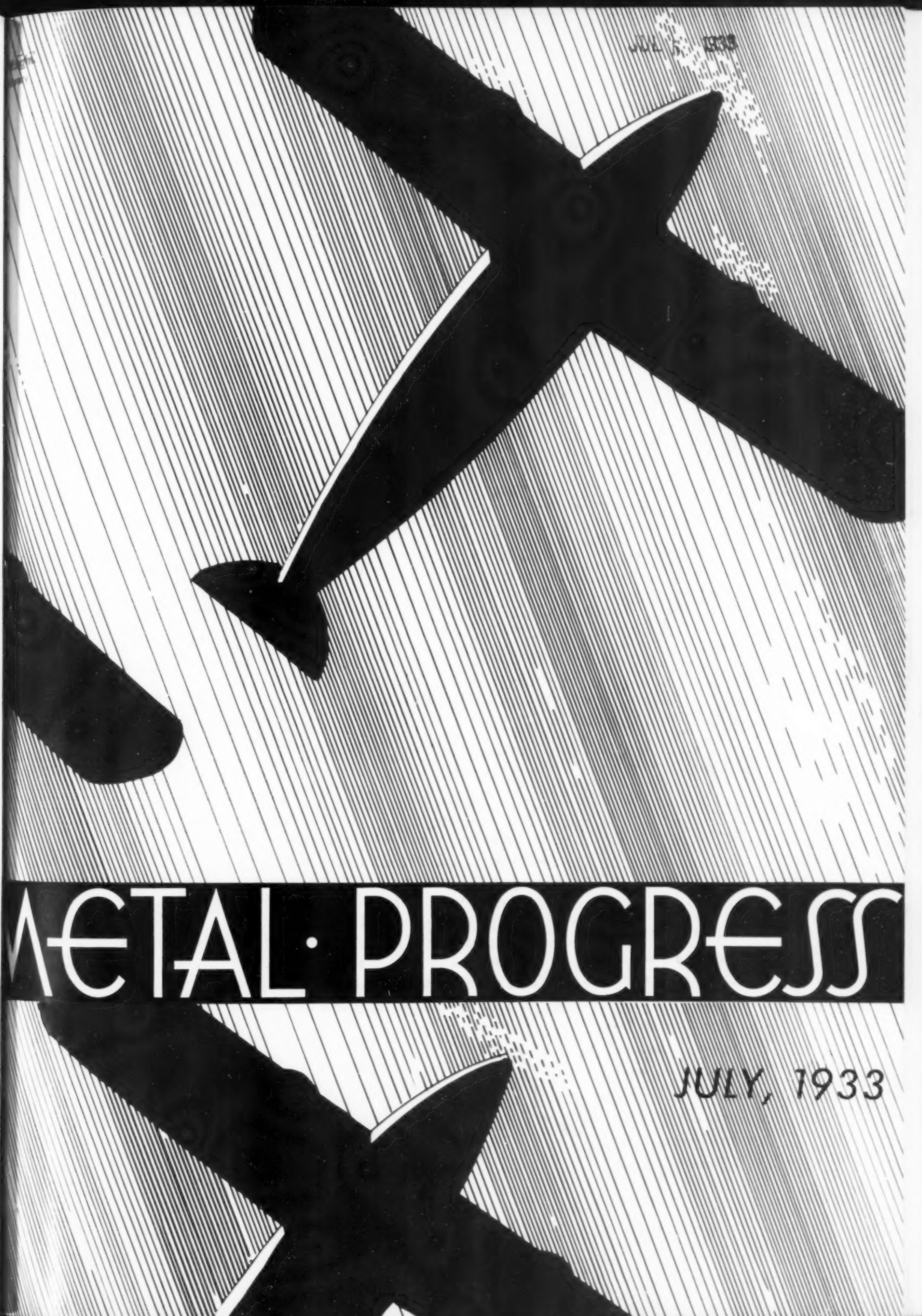
METAL·PROGRESS
JULY, 1933

A TRIP TO THE METAL CONGRESS

DETROIT • OCTOBER • 2 • 6

Men who are making metal history are men worth meeting. You will find them concentrated in Detroit the week of October 2nd to 6th.

Five of the most active and progressive technical groups in the nation are co-operating in this year's Metal Congress—

THE WIRE ASSOCIATION
AMERICAN WELDING SOCIETY
AMERICAN SOCIETY FOR STEEL TREATING
IRON AND STEEL DIVISION, AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS
INSTITUTE OF METALS DIVISION, AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS

The papers presented at the technical meetings of these groups will cover the radical developments and discoveries of a year of amazing progress in the metal industry. The displays at National Metal Exposition will center on the same theme. No man concerned with the future of the metal industry can afford to be absent from this year's—

METAL CONGRESS AND NATIONAL METAL EXPOSITION

METAL CONGRESS has been aptly termed "a mental pickling bath and tumbling barrel combined." The fact that year after year it brings together men from the farthest corners of the metal industry should be impressive to any metal man who has never given himself the benefits of attendance.

Particularly important at this year's congress will be the wealth and variety of plant inspection trips afforded by Detroit and the Detroit area. Outstanding examples of both mass production and precision manufacturing will be included.

July, 1933
Vol. 24, No. 1

METAL PROGRESS

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Ernest E. Thum, Editor.

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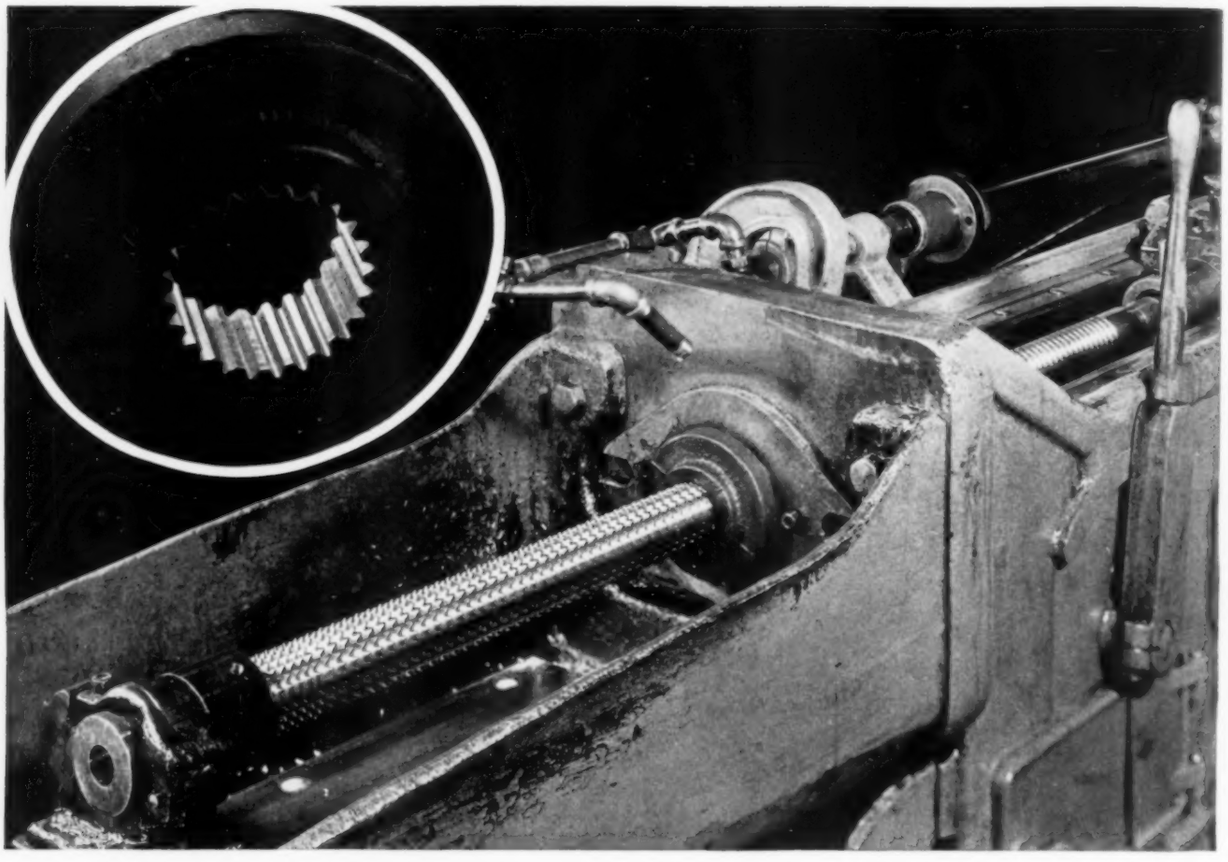

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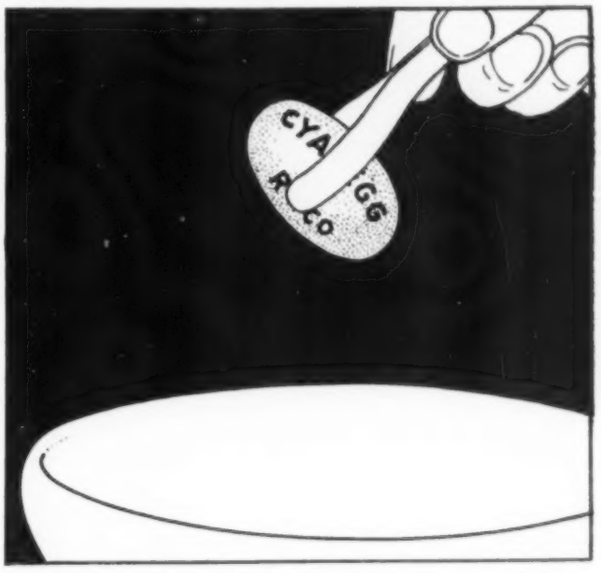

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Photo at Cleveland Tractor Co.

The Night Shift at Work Again!

By R. D. Alger and
G. C. McCormick
General Alloys Co.

HIGH ALLOY CASTINGS

their foundry problems

ANY consideration of foundry practice must first recognize that the heat and corrosion resisting alloys differ among themselves, metallurgically and physically, to the extent that brass differs from steel.

The beginning of complex alloys for high temperature duty was marked by the advent of high nickel-chromes containing 60 to 80% nickel, 15 to 20% chromium, and with small amounts of iron, silicon, titanium, and a variety of other elements. These materials are in no sense *steel;* they are nickel-base alloys having an entirely distinct metallurgy and practice from alloy steels.

Between these high nickel-chromium alloys and those whose principal ingredient is iron (18-8, 18% chromium, etc.) is a tremendous difference in properties, among which may be enumerated heat conductivity, strength retention at high temperatures, oxidation resistance, response to heat treatment, casting properties (chilling, gating and pouring practice and control of solid non-metallic impurities) and capacity to resist repeated heating and cooling.

Development of the Art — The foundry practice for the principal types of corrosion and heat resisting alloys now used in considerable tonnage had its foundation to a large degree in the earlier practice developed for the high nickel-chromium alloys low in iron. The unusually precise and detailed methods for manufacturing the latter were imposed by the exacting sectional requirements and inspection for materials costing initially $1.00 to $1.50 a pound.

The technique and much of the current information by virtue of which the high nickel-chromium founders formed the foundation for this entire series of alloys have been developed by engineering organizations whose foundry operations are supplementary to design, foundry technique, and engineering work.

It is obvious that there are two approaches to the foundry problem for lower chromium-nickel alloys with iron — one from experience with high nickel-chromes and the other from ordinary steel founding experience. An unfortunate and confusing commercial situation often develops in the competition resulting from companies approaching the problem from these two angles.

In producing the lower grade alloys, such as the straight chromium-irons and the chromium-nickel-irons ("lower" here is used in the sense of lesser alloy content), the problem for the alloy foundryman on the one hand becomes one as to how much high class foundry work must be eliminated to meet the present day

commercial situation. On the other hand, the steel founder coming into the alloy field is confronted with the converse problem as to how much his steel practice must be improved and elaborated to produce castings for reasonable service.

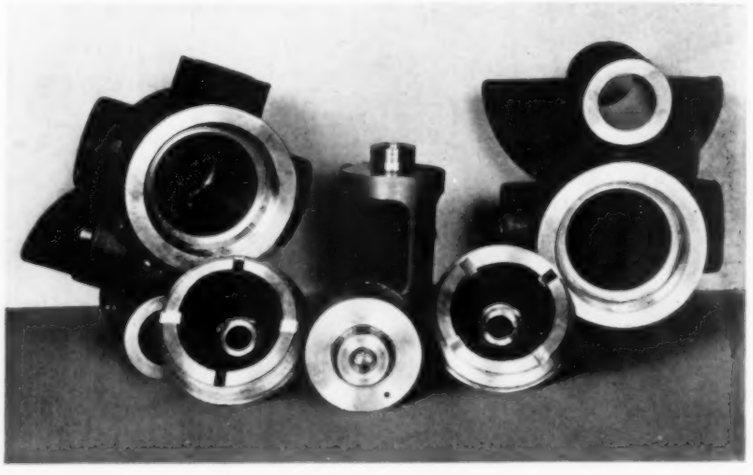
Design — Among the most important considerations is that of design. Generally speaking, alloys high in chromium and nickel have the common characteristics of narrow pouring ranges and high volumnar and linear contraction. If castings are designed along the lines customarily followed for cast iron or cast steel, combinations of thin and thick sections frequently result, which, because of differential cooling rates, aggravate this high volumnar contraction. The result is a product with shrinkage voids and other mechanical imperfections.

Expedients to minimize the shrinkage effect are not always desirable or completely effective. The utility of risers is limited on account of the narrow fluidity range of the alloys; furthermore many risers mean much scrap from trimming, and this is an important factor in raising the cost per pound or per piece of the finished part.

Chilling is not always effective because of (*a*) frequent inaccessibility to chilling of the areas that cause trouble, (*b*) limitations in the size of chills which may be employed, (*c*) interference of the design, (*d*) rough surface — or "turbulent condition" — of the casting produced against the chill, (*e*) the metallurgical differences, extremely important in chemical resistivity, set up by the rapid cooling of the chilled areas as compared with those cooling at a normal rate in the sand.

To effect the maximum of metallurgical and mechanical uniformity, wall sections of castings should be as uniform as possible throughout all parts, and sections should generally be held to the minimum permissible by the working conditions and by the requirements of foundry practice. In this connection it is well to bear in mind that the higher technique of alloy founding frequently permits the foundry to make thinner wall sections successfully than would be expected by those not familiar with the art.

The minimum thickness which may be employed will vary from $\frac{1}{8}$ in. and $\frac{3}{16}$ in. in certain specialized classes. Maximum is $\frac{3}{4}$ in. or 1 in. Occasionally heavier walls are permissible when the weight of a casting runs to several thousand pounds, and where the free flow of liquid metal is badly interrupted by combinations of cores or intricacies in design.



Rotary Valve Bodies With Complicated Multiple Ports, With Plugs and Caps Cast from 18-8

For all high temperature applications (and for many applications at normal temperatures or temperatures below 1000° F.) the designer should studiously avoid the creation of self-distorting sections, such as channels, unbalanced beams, tees, and the like, which because of mass distribution, and ratios of surface to mass, present opportunity for large differentials in the rate of heat absorption or dissipation, thus creating distortion or stresses tending to distortion, which in a short time result in observable deformation of the parts, and which, if repeated with frequency, will eventually cause failure by cracking due to what is known as "heat fatigue," or self-rupture.

Space will not permit a full discussion of all these factors. Designers should use every opportunity to consult with foundrymen in re-

spect to details, and such cooperative activity will be well rewarded.

The high alloy castings should not be looked upon simply as more durable substitutes for previously used metals. In order to secure the maximum results from cast alloys, patterns should be specially made — although there are instances in which the pattern equipment is interchangeable. It is strongly urged that the pattern be constructed with due regard for the method of molding planned by the foundry, and for the limitations and casting requirements of the particular alloy to be produced.

If designs for low temperature corrosion resistant parts, such as pressure fittings and valves, are based on experience with the more common cast materials, it will frequently be very difficult to produce pressure tight castings. Deep seated shrinks, or draws uncovered during machining operations, result in losing a casting (plus the cost of machining) that might originally have withstood a pressure test.

These features are particularly common when castings are produced from patterns having large allowances for machining commonly employed in steel and gray iron, but which are unnecessary and excessive when castings are to be made in high grade alloys by a competent alloy foundry.

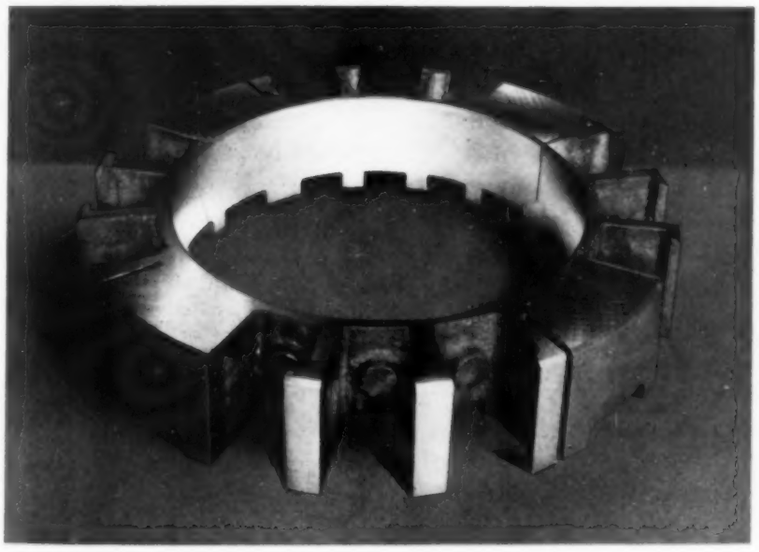
Risers and Gates — Riser and gating practice is an art in itself, and is by no means an elementary foundry problem. Let it suffice that the peculiar properties of these alloys when liquid require the exercise of much ingenuity in designing and placing the gates and in the location, size, depth, and shape of the risers.

High pouring temperatures and peculiar scouring or cutting characteristics of these molten alloys severely tax the bond and cohesiveness of the molding sand. If washing or sand erosion is to be avoided, it is obvious that careful attention must be given to the location of gates. Washing of the sand must be avoided, yet the metal must flow at a sufficient speed and volume to fill the cavities without cold-shuts and mis-runs.

Expedients to avoid mechanical introduction of dirt embody the use of various skimming devices, not always of familiar type. The effectiveness of the familiar skimming gates depends upon the mass of metal adjacent to the casting wall. If such a practice were duplicated in the high chromium-iron alloys and the common iron-nickel-chromium alloys, almost all of them would have severe shrinks and draws at the junction of gate and casting wall.

Cleanliness is of vital importance, and experienced foundries employ special precautions in slagging, pouring, ladle design, and gating practice, all of which contribute to this important end.

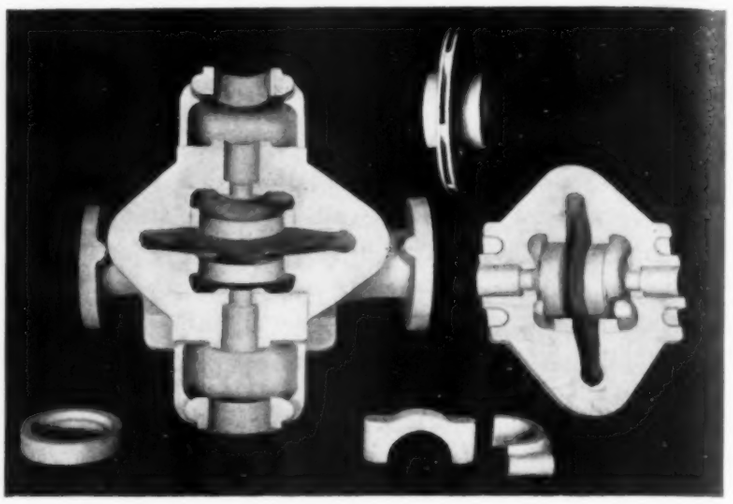
Sand Selection and Mixtures — The service required of the finished part determines the type of sand to be used in molding. For many castings for high temperature or severe corrosion service, a dry sand process is essential for satisfactory performance. This is particularly true for corrosion resistant castings that have much machining to be done, or on all parts requiring polish on any sizable areas.



Adjustable Bridge (Cast and Accurately Machined) for Ports to Be Inserted in Blow-Out Valve Used in Manufacture of Heavy Chemicals

Skin-dried or air-dried molds may sometimes be employed effectively. Where price is the controlling factor it is necessary to use cheap green sand molds. Buying or manufacturing on the basis of price first has been disappointing, to say the least, and has certainly been of no benefit to the user nor to the foundry industry at large.

Molding sands are selected for specific properties of refractoriness, ramability, permeability, resistance to high temperature, and erosion. Some natural bonded sands are used, as well as a considerable quantity of sands with synthetic bond. Correct bond and moisture contents must be maintained, and reblending and tempering operations must be closely controlled.



Pump Made of Alloy Containing About 26% Cr, 16% Ni. Body weighs 119 lb., cover 39 lb.; the case rings and bearing cups 3 lb. each, and the enclosed impeller 15½ lb.

Core sands are usually specially selected and synthetically bonded to produce sufficient firmness when baked, and yet a very definite friability when hot. Because of high contractions of these alloys, hard cores suitable for common steel or gray iron would be disastrous. Cores for hollow members (tubes and the like) must therefore be collapsible, either by disintegration under the heat of the metal, or by collapsing through exterior mechanical means. It is obvious that a delicate balance must be maintained to obtain sufficient mechanical strength to withstand the pressures developed within the mold while the metal is liquid, and yet disintegrate sufficiently rapidly to avoid rupturing or severely straining the casting itself, as it cools and contracts in volume.

Chemical Specifications and Charge Compositions — There is probably no aspect of these alloys which is subject to as much abuse, misunderstanding, and misuse as is the chemical composition or analysis. Users and manufacturers alike refer to 65-15, 60-12, 35-15, 28-10, 24-12, and 18-8 with an offhandedness that is worthy only of materials of complexities no greater than S.A.E. 1025.

Specifications for rolled material (wherever available) have been commonly employed to purchase castings. It is one thing to cast ingots, simple in shape, which can be poured into iron molds with dull metal. If they have any surface defects they can be removed by grinding. It is an entirely different thing to pour an alloy, of similar content in nickel and chromium, into an intricate shape molded in sand, and meet all the conditions of surface and soundness of sections necessary for the intended service conditions. This requires much higher pouring temperatures than are necessary for ingots. Even after these temperatures are attained in an alloy of extremely low carbon content, there exist three important hazards irrespective of the method of melting: (1) Danger of excessive gas absorption during the time in the furnace required for superheating (since the gas absorption curve rises very rapidly above normal pouring temperatures) which enhances the subsequent danger of blowholes; (2) the greater possibility of contamination from the erosion of the refractory furnace lining, and (3) further danger of contamination by the extreme cutting action of the excessively hot metal running over sand in the molds.

Particularly in the manufacture of corrosion resistant castings our firm has maintained that a higher carbon content is necessary and desirable together with corresponding higher chromium and nickel content in the nominal 18-8 and 24-12 alloys. Chemical specifications

normally employed for 18-8, having a narrow range of chromium and nickel (and frequently low carbon) have not been difficult to attain in steel plants where nothing but ingots is cast.

Experience in several industries where these cast alloys are used for corrosion resistance in conjunction with wrought products of the 18-8 type, indicates that the higher chromium and nickel alloys, such as the 24-12 type, can advantageously carry higher carbon, which results in better castings at substantially lower all around costs.

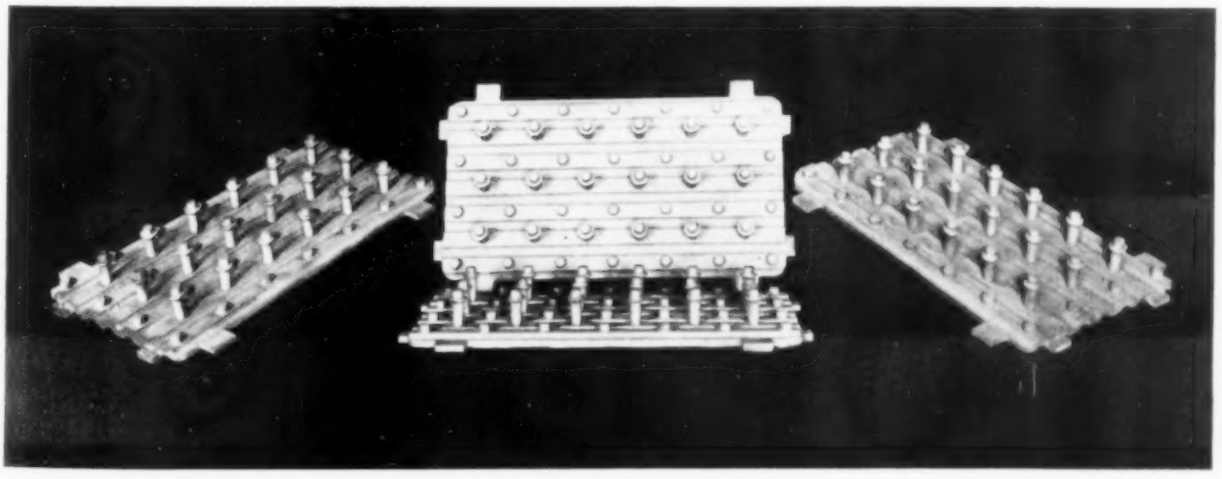
No chemical specification yet devised insures the user of anything more than an exact amount of chromium, nickel, and other elements specified. Chemical analysis alone does not provide for metallurgical uniformity or cleanliness, nor does it place any limitation on how the required composition is to be secured. For example, 18% chromium and 8% nickel may be secured by charging any one of several grades of ferrochrome, metallic nickel, and ingot iron — all virgin metal — or the same analysis may be made by remelting scrap, correcting for melting loss by adding small amounts of ferrochrome, and occasionally nickel.

Producers of plain carbon steels and brasses and bronzes have found that for a high quality product the raw material must be selected for its uniformity of composition, and the accuracy of its analysis, assumed or determined. Even more is it true that in melting for high alloys, any scrap must be selected with close regard for its initial composition, probability of its uniformity, freedom from oxide, dirt, and other harmful substances, after due consideration has been given to its service history.

The employment of excessive quantities of burned or contaminated scrap, and conversely the use of little or no new material in melts, has a profound bearing on the cost per pound of the delivered casting — and likewise the cost per service hour! There is no mesmeric metallurgy as yet developed for the melting of these alloys which will convert bad material to good, nor can the alloy founder add the problems of refining the steel bath to his other cares.

Conclusion — It is extremely difficult, even in much more space than here available, to treat all the factors of foundry practice, and to evaluate fully the importance or the ramifications of these different factors.

The alloy foundries, who are making a sincere effort to produce high grade material, properly engineered and properly applied, and the users of these castings (and wrought products) who have confidence in the economic utility of these materials of construction, are writing the early history of an industry which today is infantile and ignorant in comparison with the size and enlightenment which coming years of sincere and intelligent effort will bring forth.



Special Design of Carburizing Box for Stacking Gears Properly. Composition of alloy: 66 to 68% Ni, 18 to 20% Cr

By Robert Worthington
International Nickel Co.
New York City

COPPER-NICKEL TUBES

their advantages for steam condensers

CONDENSER tube corrosion has always been a serious source of expense, and as well one of the factors that have limited the efficiency of power plants.

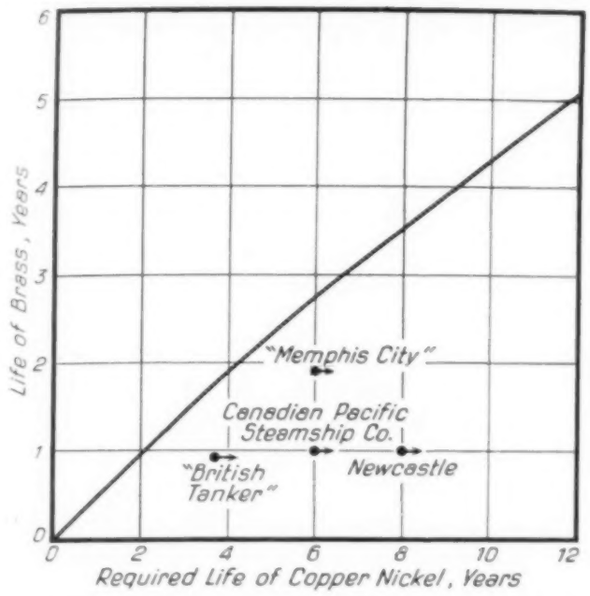
When the condensers of a trans-atlantic ship require retubing every 20 months, obviously the corrosion conditions are severe; several thousand tubes costing in the neighborhood of $5000 makes a considerable outlay. Yet a further significance rests in failures — within a few months after installation scattered tubes begin to fail. Condensers cannot be shut down; the ship must continue on to port, often several days away. It is a simple matter also to introduce sawdust into the inlet water and so put a stop to the leaks. But this is a temporary expedient at best and not a preventive.

Brass tubes of the Muntz metal type were at one time used for both steamship and land plant condensers. It was then found that the 70:30 copper-zinc brass tube was more suitable for sea water conditions. Still later the addition of 1% tin to this composition was found to improve its corrosion resistance, and this mixture, known as Admiralty brass, is now generally used in condensers both on shipboard and in shore plants condensing steam with salt water.

Design of modern marine turbine condensers calls for a much higher heat transfer efficiency than required in condensers on reciprocating engine ships. This higher efficiency is obtained by the use of higher cooling water velocities. Admiralty brass tubes, satisfactory for the most part on non-turbine ships, often give discouraging results when handling these higher velocities on turbine ships. One company operating a number of twin screw ships in trans-equator service has been forced to retube each condenser at intervals averaging 22 months. With 4000 tubes in each condenser the cost per ship for tubes alone, aside from the labor involved and the danger resulting from leaking tubes within the 22-month period, runs as high as $4000 a year.

Land plants as well as ships have their difficulties. One utility company, among others that might be quoted, has given an average annual figure of $100,000 for condenser maintenance — largely for the replacement of tubes. In this case Admiralty brass tubes have had a life of two to three years.

As will be discussed later, it is known that



Life Required of Copper-Nickel Tubes to Equal the Costs of Brass Tubes, Interest Included. Arrows indicate the life already obtained from copper-nickel, with tubes still serviceable, under conditions where brass failed in less than two years

corrosion resistance depends upon the nature of the films that develop on the wall of the tube. These films are made up largely of corrosion products, but in part also of solids precipitated out from the water. If the films are adherent, compact, and continuous under the impingement of high velocity circulating waters carrying quantities of entrained air bubbles, the tube is a resistant one. If, furthermore, the film should rapidly heal, where for any reason it suffers local breakdown, the tube will also be a resistant one.

Once a non-healing type of film is broken, corrosion takes place rapidly at or around the exposed area. Sometimes the corrosion takes the form of isolated pitting, sometimes of a connected series of pits, sometimes of grooving. Though usually taking place at the inlet ends, pitting develops frequently down the length of tubes, depending on where the air bubble streams are the most effectively erosive. High velocity, a critical angle of impingement of the bubble, and a critical bubble size are factors in producing the erosive force that will damage the protective film.

Admiralty brass tubes, which ordinarily stand up for 10, 15, 20 years in the condensers of reciprocating engines, often fail in one to four years in condensers on turbine ships. The films that form on these tubes are successfully protective against the milder velocities of the reciprocating engine condensers, but break down and fail to form again under the more violent impingement of the water in turbine condensers.

On the other hand, copper-nickel tubes containing 20% of the second metal, due to the nature of the film formed, have under these same conditions several times the resistance of brass tubes. This better resistance lies in the physical nature of the films, which are more compact and adherent than those on brass, and consequently are more stable. Furthermore, the copper-nickel tubes have an inherent self-healing character that is of great importance.

Copper-nickel condenser tubes came into general use eight or ten years ago, when it was recognized that a much better tube material than Admiralty brass would have to be developed for the increasingly severe conditions of marine turbine condensers. The increase in heat transfer efficiency that accompanies higher velocity cooling water could not have been safely and economically realized unless a more resistant tube than brass had been found. This marks the advent of the copper-nickel tube.

At the present time the records show that over 300 vessels of commercial lines and navies carry complete installations of copper-nickel tubes, and that well over 2,000,000 tubes are in service. In addition a number of land plants are using these tubes; the tidewater stations of a single company have 150 tons.

Costing about twice as much as Admiralty brass, copper-nickel tubes must give two or three times the life of Admiralty to be economical, based on tube cost alone. The curve indicates this relationship.

Four comparative life records are plotted. The vertical ordinate of each of the four arrows represents the average life of previously used Admiralty brass tubes in three steamships and one land station (Newcastle-upon-Tyne, England). In each case the first set of copper-nickel tubes is still in service, with no indication of what their eventual life will be, despite the fact that the best previously known alloy failed in less than two years in each of these situations.

Economy, as measured by the tube costs alone, is very apparent. The advantages of a condenser that does not require continual dosing with sawdust and opening in port for plugging leaking tubes are also very real, although not of a nature that may be expressed quantitatively.

The 2,000,000 tubes in 300 other ships have their own stories to tell!

General Mechanism of Corrosion

Corrosion failures of brass tubes in salt water are of two main types. Condensers for reciprocating engines are ordinarily long-lived — 10, 15, 20 years — with failure taking place ultimately by a process of "dezincification." Cooling water has a relatively slow velocity and tube wall temperature is relatively high. Under these conditions both the copper and zinc dissolve from the tube, and the copper then deposits back on the metal. Eventually the tube becomes transformed into a spongy copper tube of the original dimensions. At times a localized type of dezincification takes place that causes a more rapid failure by penetration. Brasses, particularly those of higher zinc content, are susceptible to dezincification, but copper-nickel is not.

A pitting action, much more disastrous than dezincification, is the characteristic type of attack in turbine condensers where the water velocity is high. Water passing through $\frac{5}{8}$ to 1-in. tubes at 6 to $8\frac{1}{2}$ ft. per sec. is in turbulent flow, and entrained air bubbles are streamed out in helical flow to impinge at points against the wall. As a result the tube suffers deep and rapid pitting and grooving at these points of impingement. A tube that has suffered impingement attack is illustrated.

A review of the electrochemical mechanism of corrosion will be useful in gaining an understanding of this action.

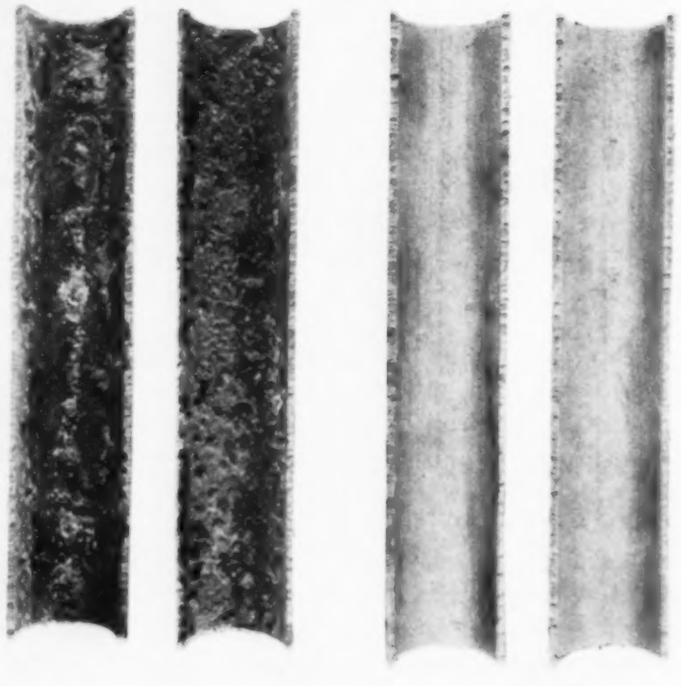
All aqueous corrosion is electrochemical in the sense that the corrosion reaction is accompanied by the flow of electric currents. Whereas these currents formerly were believed to originate in potential differences between heterogeneous grains of metal, it is now known that the force producing corrosion is much more frequently derived from local differences in the concentration of salts, ions, or gases in the solution.

These differences, or "concentration cells," so far as they are practically important in causing corrosion, are of two types:

1. Concentration cells due to differences in dissolved oxygen content (metal in contact with solution higher in oxygen is cathodic to other metal in contact with solution lower in oxygen).

2. Concentration cells due to differences in metal ion concentration.

When current passes through metal electrodes in a solution, metal tends to go into solution at the anode (entering place) and to deposit at the cathode (leaving place). In most actual corrosive conditions these reactions are retarded, particularly by lack of noble metal ions in the liquid in contact with the cathode. (By



Admiralty Brass (Left) and Copper-Nickel Tubes After Service in the Same Condenser. The brass had been in service for less than 12 months, the copper-nickel for over four years

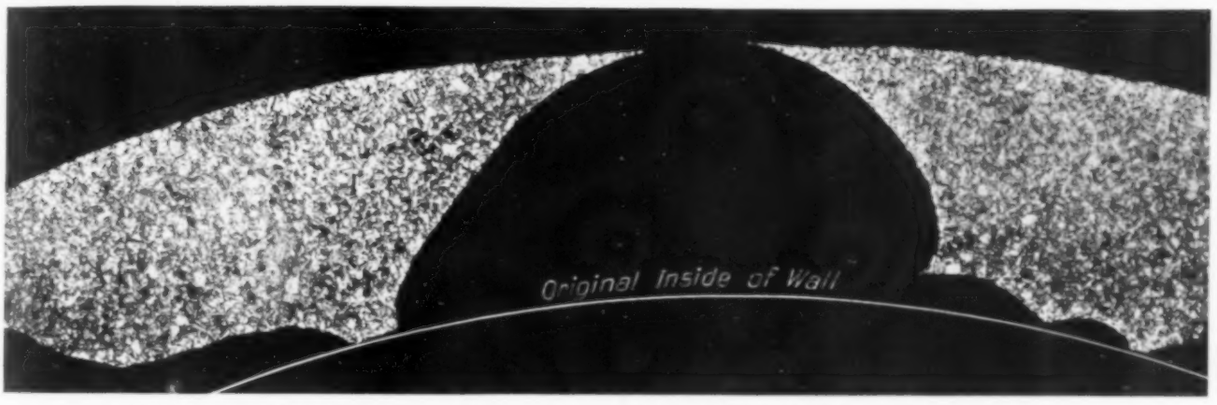
"noble metal" is meant one that dissolves with difficulty but deposits easily.) As a consequence hydrogen ions are discharged and the cathodic surface is blanketed with the resulting hydrogen atoms. Where there is plenty of oxygen it can react with the hydrogen to form water, thus allowing the cathodic reaction to continue and the current to pass. In this way oxygen-rich areas become cathodes, inducing corrosion in their neighborhood at oxygen-poor areas, which are therefore anodes. This is the differential oxygen concentration cell first mentioned above.

In the metal-ion cell, a high concentration of noble metal ions produces a cathodic area by the tendency to deposit, thus inducing corrosion at a neighboring area low in noble metal ions, the anode. Copper is the common metal most susceptible to metal-ion cell action.

Differences in oxygen concentration probably always exist. Oxygen is absorbed by solutions from the air and, considering temperature and pressure variations, solutions are probably never in complete equilibrium with air. Metal-ion differences develop naturally as corrosion progresses, the metal ions tending to build up more rapidly at anodic areas than they do at cathodic areas.

Although differences in dissolved oxygen and metal-ion concentration are thus normally to be expected, these differences are not ordinarily great enough to cause trouble by themselves. Nevertheless, the slight corrosion that does result leads to films of liquid and solid corrosion products that become the agency of much more powerful concentration cells.

In fact, irregular distribution of corrosion product is the most important condition favoring intense localized corrosion. At breaks in these solid films oxygen finds ready access to promote the cathodic reaction at the expense of corrosion at the surrounding shielded areas. At these same breaks in the films, metal ions (derived from the corrosion that has taken place) are removed more rapidly than are the metal ions that have developed beneath the surrounding film. This results, therefore, in a metal-ion cell that tends to cause accelerated corrosion at the film-free area.



Photomicrograph of Punctured Admiralty Brass Tube After 18 Months' Service on Shipboard

It is to be noted that a discontinuous film tends to set up both an oxygen cell and a metal-ion cell, but that the two types of cells oppose each other. The more powerful of the two cells will determine whether the most penetrating corrosion will take place at the shielded area or at the exposed area.

It is also to be noted that each cell acting alone tends to suppress itself both by lessening the concentration differences of the cell itself and by promoting, or allowing to become operative, the concentration differences of the other and opposing type of cell. These are *tendencies* — under some conditions, it is true, they may not become fact. Thus either type of cell, if conditions are appropriate, may continue active until failure of the metal.

Uneven velocity of solution is a condition

that favors the setting up of intense action. Its principal effect is to accentuate the cells that originate in the uneven distribution of films, either by bringing a greater supply of oxygen for the cathodic reaction or by carrying away metal ions with greater facility and so promoting the anodic reaction.

A second effect of uneven velocity is a tendency to cause local damage to the protective film, a particularly important effect in the case of condenser tubes. A third is to thin down locally the liquid friction film and the solid product film and so promote diffusion of the reactants and reaction products of corrosion.

The action of sea water on brass under quiet or mildly agitated conditions is not rapid, particularly when the metal becomes covered with a continuous layer of corrosion products or other precipitated salts. The friction films of solution and the solid product films lower the diffusion rates of the reactants and soluble products of corrosion. The power of the concentration cells that develop is weak.

With increasing water velocities and turbulence there comes a critical set of conditions where the solid layers of products are damaged or prevented from forming. Sea water passes in turbulent flow through the highly efficient condensers of turbine power plants and moreover is charged with entrained air bubbles that impinge at an angle against the tube wall. At points along the wall the combination of velocity and air-bubble impingement becomes drastic enough to wear off locally the layer of solid products, thin down the friction film of solution and set up a metal-ion cell of strong and persistent corrosive power.

Turbulent Flow Increases Corrosion

The rapid corrosive action of high velocity sea water carrying entrained air bubbles on Admiralty brass as compared with air-free water has been demonstrated in laboratory tests by Bengough and May, and reported in 1924 to the British Institute of Metals.

It is recognized that the conditions of this test do not duplicate the usual conditions within a condenser tube. Nevertheless, they found a corrosion rate of 0.14 in. per year, which is within the range of what happened to tubes which have been known to have been penetrated by pitting in a six months' period of service.

Why do some metals resist impingement attack conditions better than others?

First it is necessary to understand that the battle-line in the corrosion process is the extremely thin, invisible layer of solution against the metal surface. This layer is stagnant. Through it the reactants must diffuse to the metal surface, and the products of corrosion must diffuse out. Diffusion is a much slower process than reaction, and the rates of diffusion through this stagnant film often control the rates of corrosion.

Again, the corrosion products of metals like copper and nickel have low solubilities in neutral salt water. They tend to precipitate out on the metal surface (or at least sufficiently close to be held, where deposited, by adhesion). The importance of these solid products lies in their obstructive effect to the diffusion to and from the metal surface. The addition of zinc to copper, as in the brasses, improves the tenacity of these products, and the 1% of tin in Admiralty brass is further improving. But far more effective than either zinc or tin is the 20 to 30% of nickel in the commercial copper-nickel condenser tubes.

The effectiveness of solid layers in controlling corrosion is not indicated necessarily by their thickness. As a matter of fact, the most protective films are often so thin as to be invisible. We must bear in mind then that the protective film that plays such an important part in determining the resistance of a condenser tube is not visible scale of varying thickness, but an inner layer so thin as to be invisible.

Obviously the production of this thin protective film and its maintenance in a complete or unpunctured condition is a major consideration. Corrosion at even a small puncture in the film may result in rapid failure. This is the weakness of brass tubes. The corrosion product films that develop, sufficiently protective so long as turbulence and impingement are not severe, cannot meet the conditions that the modern, high efficiency turbine condenser imposes. It is true that brass tubes over the greater part of their length remain sound, but attack in a single small localized area is enough to destroy their usefulness.

By E. J. W. Ragsdale
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Philadelphia

TO WELD 18-8

minimize time at heat

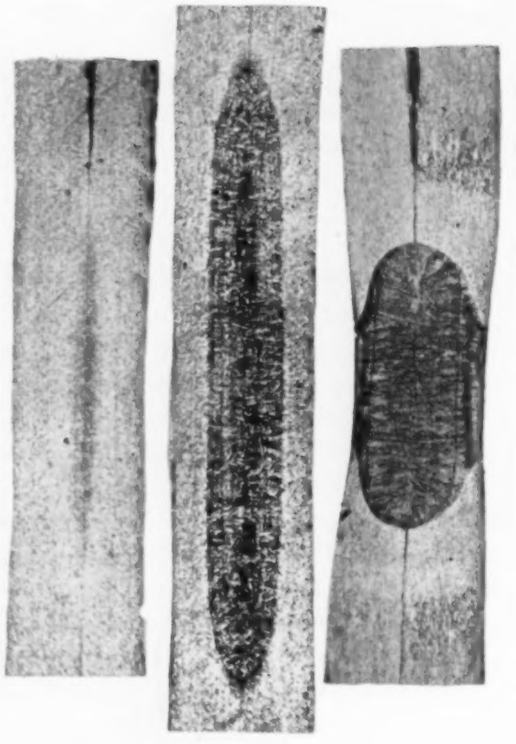
SPOT welding, in the ordinary meaning of the term, is a method of forming a joint between overlapping sheets or plates wherein regularly spaced areas, roughly circular, of the faying surfaces are welded. It is done mechanically by gripping the seam between two snub-nosed welding dies made of hardened copper and passing a low voltage, high amperage current through. (Equipment may be as fixed as a punch press, or as portable as an arc welder.) Resistance across the joint generates the heat and the electrode grip furnishes the slight pressure necessary for a localized weld. One spot is usually made at a time owing to the difficulty of subdividing the current properly. A successful alternative consists of pressing little teats on one faying surface, and welding several at a time between flat vise-like electrodes—a process known as projection welding. This article will concern itself with the problem of welding a single spot at a time. "Shotweld"-ing is a trade name used to denote the origin of an automatic process where the current is imposed for a very small fraction of a second, and all conditions of current application accurately controlled.

Chromium-iron alloys, both medium carbon and very low carbon, may be spot welded without difficulty, but the joint and the surrounding metal is affected adversely, as has been pointed out by previous writers on this subject; namely, the martensitic steels air harden and the ferritic chromium-irons experience rapid grain growth at welding temperatures. Both of these conditions tend to produce brittleness.

The austenitic alloys, such as 18-8, on the other hand, lend themselves peculiarly well to spot welding methods. The fact that the electrical resistance is from eight to ten times greater than that of mild steel, together with its bright, scale-free surfaces, makes ideal conditions for resistance welding (and particularly in steel cold rolled to high tensile strengths). Its lower conductivity for heat and lower melting point also indicate why spot welding will require less heat than the same gage of common steel. At the welded spot the metal has been heated to more than 2000° F. and then quenched (the heat being absorbed by the surrounding cold metal) — the very procedure for the proper heat treatment of 18-8. Consequently the welds are tough and ductile; they may be twisted nearly to 90° before shearing. Unlike spot welding practice with ordinary steel, 18-8 may be welded through a large number of thicknesses.

As in all operations on 18-8, it must be borne in mind that this material loses some of its really remarkable non-corrosive qualities

and becomes brittle if held for a considerable time between 800 and 1500° F. It is generally held that the cause of this is connected with a precipitation of carbides from out of the solid solution (austenite), the accumulation of these carbides at the grain boundaries and a simultaneous impoverishment of these regions in the corrosion-resistant element chromium — now locked up in the carbides. The tendency has been mitigated by reducing the carbon content or increasing the chromium and nickel, adding certain restraining alloys, and by a definite program of cold work and heat treatment. But in any welding operation it is important to minimize the area heated and the time of passing through the dangerous range of heat — a matter which is difficult to arrange in gas or arc welding, where a zone parallel to the seam is adversely affected and is not above suspicion. In spot welding the "dwell" of the current likewise assumes the utmost importance.



Welded Areas Between Two 0.010-In. Sheets of Stainless Steel, Cross Sectioned, Slightly Etched and Magnified 40 Diameters. Sample at left had insufficient heat and is brittle; center sample is correct; right sample had too much heat and sufficient corrodible metal has been produced to extend to the outer surface.

In all resistance welding, including spot welding, the heat developed is proprotional to I^2RT, where I is the current, R the total surface resistance and internal resistance between electrodes, and T is the time of application. If the heat is just sufficient to fuse the metal at the abutting surfaces in line with the electrodes, the heat will be quickly dissipated into the surrounding material, acting as a chill mold. The volume of metal to be heated is quite definite for a given thickness of steel, and the current and time must be controlled accurately.

A very long time for a small current would result in complete dissipation of heat by conduction and radiation — and no weld. A relatively shorter time might result in a weld, but still with a large heat loss to adjacent material. The shorter the time and the more accurately gaged the current the narrower will be the temperature gradient, as well as the period of cooling. Here, too, enters another factor, namely the period of cooling, for it takes time to precipitate carbides, or embrittle, and to change grain structure. A heat operation completed in an incredibly short time leaves the adjacent material in a healthy state, but if the application of the heat is too long protracted, the weld will be like a rivet surrounded by mush. This is particularly so when steel cold rolled to high tensile strengths is welded.

A very short dwell of current is necessary, and while any spot welding apparatus may be adapted for use in connection with stainless steel, the best results are to be had with one where transformer and timer are designed for the specific purpose intended, and where the work is not subject to the control of the operator. Strangely enough, a commonly-held opinion has it that *time* is a prerequisite of heating and that the operation cannot be unduly hastened. As a matter of academic interest, in the development of "shotweld"-ing, times of dwell were reduced to as low as 0.0001 sec. Actually, few cases require a time less than half a cycle (1/30th of a second for 60-cycle alternating current). Unfor-

Equipment With Pincer-Type Contacts for Making "Shotweld"

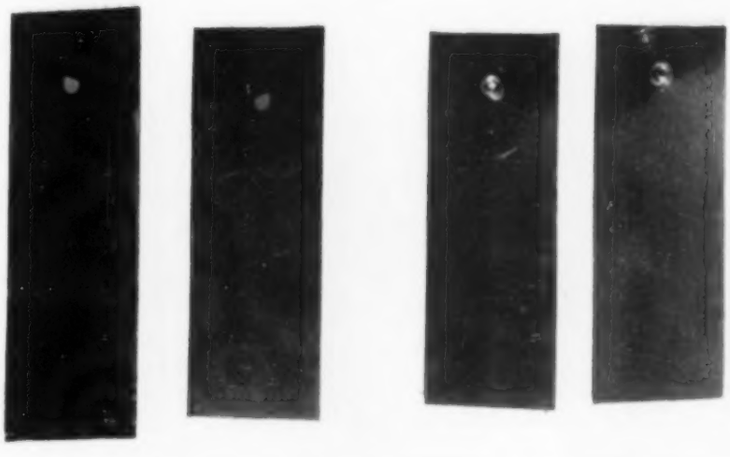
tunately, no definite relation can be established between time of dwell and total thickness of the material to be welded. This condition is so related to the type of welding tools employed and the capacity of the apparatus that any statement would be misleading rather than helpful.

Correct technique to insure uniform welds involves careful control of a dozen variables, such as clean surfaces, good contacts, electrode pressure, and voltage line drop. Since surface appearance is not a reliable criterion of the properties of a weld we at Edward G. Budd Mfg. Co. have found it necessary to build a precision recorder into the welding machine for fabricating cold worked 18-8 into highly stressed structures, such as airplane wings and interurban car bodies. The supervisor can then set the recorder for pressure, current, and dwell, properly proportioned to the gage of the material in order than an optimum weld strength be obtained and that the surrounding material be not affected deleteriously. The workman, then, has only to fix the electrodes on the proper spot and close a switch. Every weld made or failed is recorded on a tape, and any variance of conditions which may produce too much or too little heat causes a bell to ring continuously until the machine is reset.

With adequate set-up, a good workman can make about 10 welds a minute on complicated work and 40 per min. on straight seams. Machine welding speeds approach 100 per min. It is interesting to note that the heat needed for a single weld in two pieces of 0.012-in. sheet is only 0.035 B.t.u.

Welding equipment should be set so that sample welds will twist 60 to 90° before shearing out. Welds vary in character from being very brittle to dead soft. A weld having small depth lacks tenacity and is apt to snap; while a soft one may be surrounded by a volume of affected metal that will fail by fatigue. Time and current relation alone determine the physical character of the weld.

For design purposes, a "shotweld" in 18-8 can be counted on for twice the shearing resistance of a rivet of like diameter and of the same material.



A Good Way to Test Welds Is to Twist Them Apart. At left is a pair which were insufficiently welded and the two parted easily, showing a matte-like spot where the joint had been. At right is a good weld, where a stud-like nib twisted out of one member.

Weld diameter should be a function of metal thickness, as well as of the general design. The diameter of the weld is strongly influenced by the amount of welding current and the time of application. Weld diameters and spacings are best determined by the crushing of test sections. The danger of a small area of fusion lies in insufficient strength, while the price of too large an area is an overly large flange and an excessive zone of annealed material, to say nothing of the possibility of carbide precipitation. In aircraft work, where the thickness of the sheet is likely to average 0.015 in., the diameter of a sheared weld should be about $\frac{1}{16}$ in. This diameter naturally increases with the gage of material until it becomes about $\frac{3}{8}$ in. in two thicknesses of $\frac{1}{8}$ in. sheet.

Of greater importance than weld diameter, or welding spacing, is the extent of fusion. This can only be absolutely determined by sectionalizing and etching. As shown by the views on page 26, the extent of fusion is sharply defined. In a good weld it should extend well into each sheet and yet not break the outer surfaces. The Budd company specifies that the overall depth of fusion should not be less than 50% of the combined thicknesses of the two sheets, nor more than 80%. Where the fusion does not extend fully into both surfaces, the weld is brittle; where it extends clear through, corrosion will result. While it is obviously impractical to sectionalize every test weld, the extent of fusion can readily be determined by two simple tests, and when these are right, the machine will duplicate them. If the weld fails by rotational shear at a less angle than 70°, the fusion has been too shallow, as is likewise the case if the weld fractures when the welded sheets are pried apart rather than to pull out from one or the other sheet. On the other hand, visual inspection will usually indicate when fusion has extended *to* the surface. True, this requires some experience, for weld appearance and weld efficiency are apt to be entirely different matters.

While normal practice is to use two electrodes (one directly opposite the other, and both of similar shape), unusual conditions often dictate welding by indirection. One electrode may consist of a pad clamped to a sheet, while the other is conventionally pointed and held against the member to be welded to that sheet. Again, both electrodes may be pointed and held against the member, some distance apart, while a copper plate rests beneath the sheet. Here, two welds are made simultaneously, the current passing from one point through member and sheet into the copper plate, then along the copper plate until it comes opposite to the other point where it exits through sheet and member. This is made possible by virtue of the superior conductivity of the copper plate over that of the combined sheet and member of steel.

Both methods find application in welding a corrugated member to a flat sheet such as is used in flooring or partitions. The sheet rests on a large copper plate and the only care is that electrodes are placed far enough apart to insure sufficient resistance in the pieces of 18-8.

Any of the many forms of indirect welding are apt to be more uncertain than in conventional practice.

Photo by Lewis W. Hine

Adjusting a Spot Welder For Making Panels

By Dartrey Lewis
Recently Research Engineer
American Chain Co.
Bridgeport, Conn.

GAMMA RAYS

to insure internal soundness

ADVANTAGES of X-rays for photographic study of the internal condition of metal castings, forgings, and welds are becoming increasingly apparent. (For instance, all joints in welded boilers and pressure vessels conforming to Class I of the A.S.M.E. Boiler Code must be completely radiographed.) Although gamma rays from radium were discovered by Becquerel in 1896 and their penetrating properties fully investigated, it was not until 1930 that they were used commercially for the detection of internal flaws in metals. In this year Mehl, Doan, and Barrett published in the *Transactions* of the American Society for Steel Treating some γ-ray photographs showing internal flaws in steel. Since that time a number of investigators both here and abroad have shown that they have a distinct field of usefulness for testing.

Gamma-rays (γ-rays for short) are the same type of radiation as X-rays (that is, they are "light waves" of very short wave length) but average about 1/10 the wave length of the rays from a 200,000-volt X-ray tube. Important differences in penetrating properties are the result, so that γ-rays supplement rather than conflict with the usefulness of X-rays. Gamma-rays are absorbed and scattered much less in passing through dense metals such as steel and bronze and consequently have greater penetrating power.

Successful γ-ray photographs have been taken through 8 in. of steel, whereas the present commercial limit for X-ray photographs is through 3 to 3½ in. of steel. As a further consequence of the greater penetrating power of γ-rays the exposure time does not increase so rapidly with thickness as is the case for X-rays. For this reason the contrast obtained is less than with X-rays, and the sensitivity to small defects is somewhat reduced. However, defects representing 2% of the thickness in 2 to 4 in. can be detected, which is usually sufficient.

Gamma-rays have a great advantage in photographing irregular shaped sections because the rays penetrate the metal with relatively little scatter, and satisfactory photographs can therefore be obtained when considerable differences in thickness of section exist. In the accompanying radiograph of the gate valve, for instance, no special precautions were taken; the object was simply placed between the photographic film and the emanation and left there over night. In photographing such irregular sections with X-rays it is either necessary to make several exposures suited to the various thicknesses, or to build out the thinner parts with lead or other dense material and to use elaborate screening to reduce fogging by scattered radiation.

Another advantage of radium is its extreme

Gamma Rays Are Not Scattered as Much as X-Rays When Passing Through Metal, and Therefore no Special Precautions Are Necessary for Thick and Thin Sections of This Bronze Gate Valve

portability. It can be taken to the object to be photographed and may be placed inside tubular or other structures inaccessible even to the most portable X-ray equipment.

A serious disadvantage is the time taken for exposure. The table on page 31 gives exposure times for specified thicknesses of aluminum alloys, steel, and copper alloys for 100 mg. of radium at 18 in. distance (based on the work of Barrett, Gezelius, and Mehl, *Metals and Alloys*, December, 1930) and are correct when using an intensifying screen in front of the film and lead foil behind. These exposures, which vary from 1½ hr. for 1 in. of steel to 7 hr. for 3 in., may be compared with X-ray exposures of a few seconds up to about an hour for the respective thicknesses. When studying metal over 3 in. in thickness, the very rapid increase in exposure time for X-rays coupled with increasing difficulty due to scattered radiation gives γ-rays definite advantage.

The disadvantage of a long exposure can to some extent be overcome by making simultaneous exposure of a number of objects, since γ-rays are of equal strength in all directions from the source. As no attention is required during exposure, overnight photographs can be taken. Thus a number of objects can be arranged spherically round the radium at distances chosen in relation to their thicknesses so that 15 or 16 hr. exposure is correct.

At the present time X-ray films and intensifying screens are used for the rays from radium, since no special films or screens have been marketed. The writer has used several arrangements—intensifying screens in front and behind the film, one screen in front and lead foil 0.006 in. thick behind, and lead foil both in front and behind. Good results have been obtained by all methods but the latter two were somewhat better. There is a large field for development here, since less than 1% of the rays have photographic effect. In this connection it is interesting to note that V. E. Pullin of the research laboratory at Woolwich Arsenal, England, reports in *Engineering*, March, 1933, much shorter exposure times than have been used in this country. With 242 mg. of radium at 18 in. distance he gives exposure times for 1, 2, 3, and 4 in. of steel as 2½, 6, 18, and 50 min.

Radium can be used in two ways, either as radium salt sealed in a small metal capsule or in the form of the gaseous emanation called "radon." The latter method is used by hospitals and has the advantage that the valuable radium itself may be kept in a safe. The gaseous emanation which collects over a radium salt in solution in water is pumped off every day or two, purified, and sealed in glass capillary tubes about ½ in. long. The protection tube also stops the α-rays and β-rays without appreciably reducing the γ-rays. Radiation from such a tube gradually decays so that at the end of the day 84% remains and at the end of a week 28% remains. A slight increase in the exposure time compensates for this decay.

Certain simple precautions are necessary for protection from the rays. The radium or radon should be stored and transported in lead containers of sufficient thickness and should be transferred from them to the position of exposure by long-handled forceps. It is unnecessary for the exposures to be made in a lead-lined room—in fact, much greater protection is obtained by keeping

at a distance than by any practicable thickness of lead which could be used to line a room. Sometimes the radium or radon is placed in a heavy lead box with holes restricting the radiation to the direction of the objects.

At the present time radium costs about $60 per milligram and although satisfactory photographs can be taken with 50 mg. (costing $3000) it is considered that for routine work not less than 250 mg. is required. This would cost about $15,000 and, on a basis of eight photographs per day simultaneously exposed in one or more groups, and 300 working days per year, interest at 6% would be 38¢ per photograph. Film costs about 60¢ per sq.ft. Labor at 60¢ an hour for 2 hr. a day is 15¢ per photograph. These three principal items of expense amount to $1.13 per sq.ft. Total cost would include various items of overhead. No allowance need be made for loss of radium, as the loss of radiating power with time is negligible (50% in 1600 years!) but there is risk of depreciation of market value.

These figures may be compared with an over-all cost of $1.05 per sq.ft. for X-ray photographs of aluminum castings made with 110,000-volt equipment in an industrial laboratory taking 25,000 films a year. This equipment cost about $5000; installation in a lead-lined room and the dark room cost another $5000. The cost of 200,000 or 300,000-volt equipment required for photographing steel and bronze would be somewhat greater than the above.

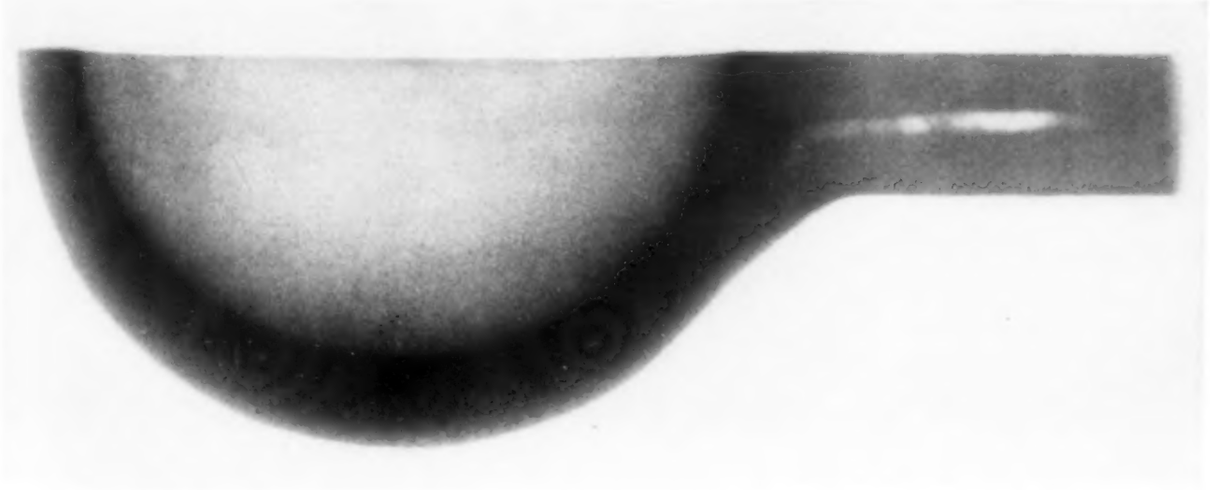
Exposure for 100 Mg. Radium at 18 In.

Thickness	Aluminum Alloys	Steel	Copper Alloys
1 inch	30m.	1 h. 30m.	1 h. 45m.
2	1 h. 10m.	3 h. 15m.	3 h. 45m.
3	2 h. 30m.	7 h.	8 h.
4	6 h.	16 h.	18 h. 30m.
5	13 h.	35 h.	40 h.
6	25 h. 30m.	70 h.	80 h.

For occasional work not justifying the purchase of radium it is sometimes possible to enlist the help of a local hospital. With the cooperation of Dr. B. M. Parmellee of the Bridgeport hospital the writer obtained a number of γ-ray photographs of steel and bronze castings, two of which are reproduced here.

The radiograph of the bronze gate valve shows that excellent results can be obtained from irregular shaped castings having considerable variations in thickness. The thickness varied from $\frac{3}{8}$ to $1\frac{3}{8}$ in. No screening or other precautions were taken to correct for scattered radiation. This casting was absolutely sound and shows that good foundry practice has nothing to fear from radiographic examination.

Another shows a cast steel foundry spoon. The defect occurred in the thickest section which solidified last and had no molten metal to feed it as it contracted. By change of gate or risers this section could have been properly fed and the defect eliminated.



Large Cavity Easily Shown in Handle of Cast Steel Ladle Where Metal Is 1½ In. Thick

Photo by Anton Bruehl for Cadillac Motor Car Co.

Stuff That Machines Are Made of

Editorial

Searching Beyond the Analysis

ONE of the most promising signs that we are progressing toward better steel is the changing attitude on the part of the producers of the common varieties. Of course, there are still numerous men who insist that steel is steel, and that the steel makers know all there is valuable to know about its uniform production, but an increasing number of the intelligent ones not only privately believe but publicly admit that something goes on in the furnace (as yet unknown) which affects the way the finished bar, sheet, or shape will react to fabrication operations and conditions of service.

Railroad engineers long ago definitely proved that transverse fissures in rails ran by heats, and if an undue amount appeared in service, the entire heat was removed from track as a precautionary measure. Yet the offending metal was made like all the others, as far as an inspector's eye could determine, and the conventional acceptance tests showed nothing out of the ordinary.

A more recently disclosed fact is that soft steels, as for instance, sheet and wire, also react by heats. That is to say, if a cold rolled sheet hardens (ages) quickly and rapidly, or if a cold headed bolt is excessively brittle, *all* the metal in that particular heat acts the same way and to approximately the same degree, whereas the very next heat from the same furnace, made to the same analysis from the same stock of raw materials, may react much more sluggishly.

Furthermore, the steel-making process (whether Bessemer, cold pig, or hot metal open hearth) has a pronounced influence on the "sensitivity" of the metal (as H. W. Graham terms it), raising or lowering the general average response of treatment to an unmistakable extent.

It is not to be inferred that the true reason of this variation by heats is to be readily found, for the physical and chemical reactions at steel-making temperatures are very imperfectly understood. But now that we know *where* to look, the search can at least start systematically.

Read Them and Weep

GEMS of technical information in the news magazine that prides itself on being "curt, clear, complete":

"Continuous sheet steel rolling — only new steel-making process adopted by the industry in the past 41 years." (Where have I been all my life, thinking I was living in a most progressive age?)

"In a cast ingot the interior pressure created by the more rapidly cooling exterior forms segregated crystalline structures which may weaken the steel." (Another thing for internal strain to answer for!)

"About 20% of an ordinary bloom is cropped off to remove flaws." (Mr. Gathmann had better advertise his big-end-up molds in *Saturday Evening Post* and catch the popular eye.)

When reporters get their history, science, and technique so cock-eyed, as they do 99 times out of 100, one is inclined to doubt the accuracy of the rest of the story.

PRODUCERS of iron ore and pig iron regard titanium as the "bad boy" of the periodic sequence. Chemists and metallurgists have been able to convert high sulphur ores and high phosphorus ores into first-class iron and steel, but so far every industrialist seems to avoid those enormous iron deposits, almost ideally situated, which carry considerable titanium oxide.

Some forty years ago, the late Auguste J.

Rossi turned his attention to this metallurgical outcast, he possibly holding the philosophy that there must be *some* good in everything created. He found it, and as outlined in a very interesting article by G. F. Comstock in one of the early issues of METAL PROGRESS, a considerable industry has sprung from these researches.

Aside from the very important outlet for titanium oxide as pigments, the metallurgical uses have been largely associated with the fact that titanium has a very powerful scavenging effect. Hence it supplements manganese and aluminum, those elements commonly used to convert unwanted elements into less objectionable compounds. An instance is the use of ferrocarbon-titanium in the manufacture of soft sheet steel and tin plate, which increases the yield of high-finish sheets from an effervescing ingot.

Carbide Control With Titanium

In the above cases, little or no titanium remains in the metal. Two interesting and valuable applications, much more recent, have to do with the far more costly stainless steels. In each instance metallic titanium remains in the alloy and by its affinity for carbon appears to cure very serious maladies or shortcomings. Thus titanium enters the class of vanadium as an element which, in homeopathic doses, controls the formation of carbide in the steel.

The first application is in the matter of intercrystalline embrittlement of the high chromium-nickel steel known as 18-8. Owing to the well-known action of nickel in lowering the critical points of iron, and the sluggishness with which carbides form in high chromium steels, the 18-8 steels appear to have a fully austenitic structure at room temperature. However, some particles of carbide form in this austenite when the metal is heated for a time (as in a piece of high temperature equipment) and these carbides, being 75 to 90% chromium, rob the matrix in their immediate surroundings of so large a proportion of this element that the residue is insufficient to protect the metal from rapid corrosion by some severe reagents like copper sulphate.

Here is how titanium works: If about six times as much of it is present as there is carbon, the carbide which is formed from the metastable austenite is largely titanium carbide, rather than chromium carbide. It has a superior carbide-forming ability, so to speak, than either chromium or iron. Chromium remains behind in solid solution with the iron, where it is intended to be for protective purposes.

The second application has to do with an even more recent alloy — the 5% chromium steels. While this is not enough chromium to class the material as a stainless or non-scaling steel, it is 2 to 4 times as good as plain carbon steel in mild corrodants and even better against heat. Consequently, many thousand tons have been used by petroleum refineries. When forged and annealed, the microstructure is ferrite with spheroidized carbides; but the steel is intensely air hardening. Castings are brittle and difficult to soften. Here, again, titanium gets in its good work. Its carbides form so readily that the 5% Cr steel (low in carbon and with about ten times as much titanium) is soft and pearlitic in structure after cooling; the chromium, relieved of its necessity for forming carbides, is free for its principal responsibility. It is no wonder that oxidation resistance is doubled.

We can expect more applications of titanium in the future. Intercrystalline embrittlement of 18-8, mentioned above, is an action precisely like age hardening, except that the carbides do not come down in a cloud, as they should, well dispersed in the matrix, but accumulate at the grain boundaries. It is quite likely that a proper combination of titanium with low carbon (near the solubility limit), enough cold work to refine the austenitic grain and produce a myriad of crystallization nuclei, and a correct temperature will give a true aging effect and result in hitherto unknown tensile strengths.

"Carbide control" is undoubtedly one of the interesting things for the near future. In its broader implications this means the whole art of hardening, but more specifically one means such things as temper brittleness, red hardness, and intercrystalline embrittlement of high alloys.

By V. B. Browne
Vice President in Charge of Research
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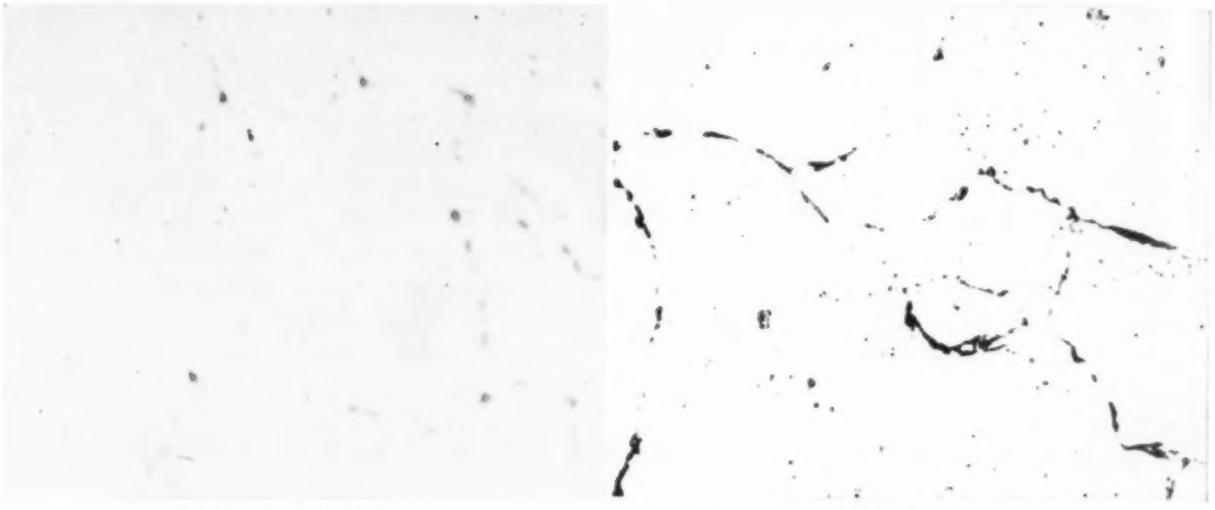
does the KRUPP TEST forecast the life of 18-8?

THE folly of accepting the results of a general accelerated corrosion test as a measure of what will occur in service, was exemplified in the case of the sulphuric acid test used some years ago to forecast the life of steel under all conditions of service. The results definitely indicated that a poor grade of steel would outlast the finest Swedish irons many, many times — a conclusion which was obviously ridiculous.

Similarly the salt spray test, primarily designed for testing the continuity of a galvanized coating, functioned admirably for this purpose, but when it was applied as an accelerated test to determine the resistance to corrosion for general purposes, it failed miserably. However, when this test is used specifically, as the Navy uses it, to measure the resistance of a metal to the corrosion of ocean water, the results can be used as a guide to forecast the life of a material under such conditions.

Engineers and metallurgists have searched diligently for some single accelerated test which might be used as a fairly accurate measure to determine the relative corrosion resistance under normal commercial service, but it is safe to say that so far no such test has been worked out, and one must conclude that each accelerated test indicates nothing more than that which is likely to occur in service when that metal is subjected to the action of that particular medium or a similar one under identical conditions. Even a slight change in these conditions, as for example, in temperature or concentration, is apt to give a different result.

When we have to deal with metals of a high resistance to corrosion the problem becomes more and more difficult. The chromium steels and the chromium-nickel steels (which by general consent have all been classified under the common nomenclature of "stainless" steels) are exceedingly resistant to the ordinary corrosive media encountered in service, and no accelerated test has yet been devised which will forecast what will happen except when the conditions of the service involved are identical to the conditions which exist in the test, or when the results of the test have been standardized with some given service. For example, the Brearley copper sulphate test, designed to test stainless cutlery, and used by him as a definition of the word "stainless," only indicates that if this steel, when hardened, tempered and polished, does not become plated with copper when immersed in this solution, it is reasonably safe to assume that the article of cutlery made from it can be used for domestic service, and specifically to resist the action of fruit juices and vinegar. It does not, however, indicate that the material is



Heated at 1200° F. for 288 Hr. Failed after 21 hr. in Krupp reagent

Heated at 1200° F. for 500 Hr. No failure after 200 hr. in Krupp reagent

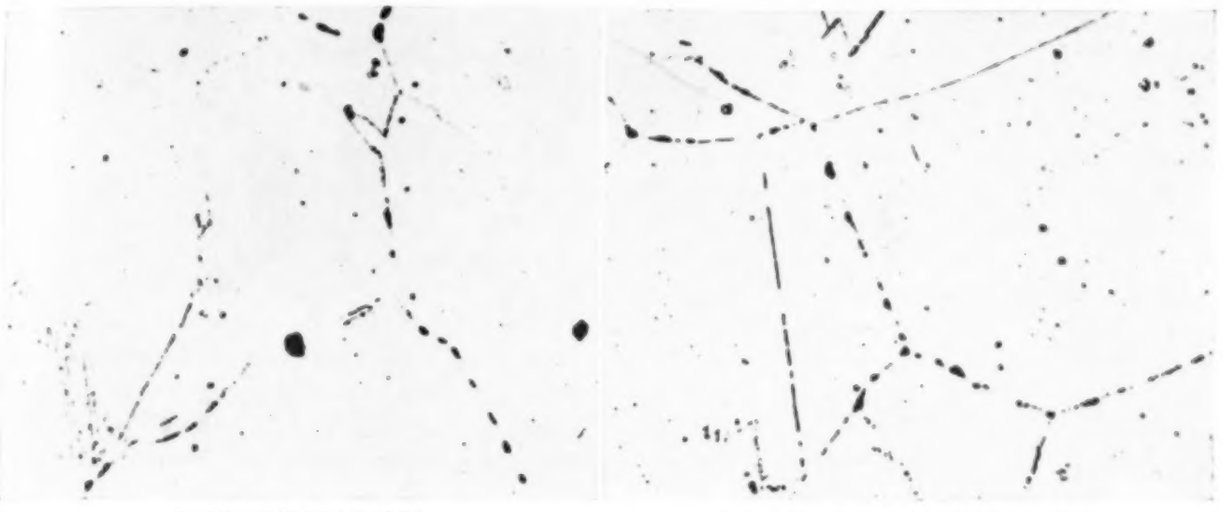
Austenitic Steel Is More Sensitive to Krupp Reagent After Short Time at 1200° F. Than After Long Time. Analysis: 0.052% carbon, 18.37% chromium, 9.18% nickel. Micros at 1000 diam.

stainless, as defined in the dictionary, and as a matter of fact stainless steel which conforms to all the requirements of cutlery tests, will stain and rust very badly under many conditions of service.

Of all the "stainless" steels the most resistant to corrosion is the austenitic chromium-nickel steel containing approximately 18% chromium and 8% nickel. When this steel was developed and commercial processes worked out for its manufacture and fabrication it was hoped that it would solve most of our corrosion problems, because its properties more nearly approach those of the noble metals. It was practically untarnishable under ordinary service, and was only soluble in certain mineral acids and some of their compounds. It developed, however, that this metal was susceptible to what might be called a disease which under certain conditions impaired its resistance to strong corrosives. The effect of this disease was somewhat analogous to season cracking of yellow brass. It was brought about when the material was used in a temperature range of from 800 to 1500° F., and subjected to an active corrosive agent. Even when the metal was merely heated to a temperature within this range and afterwards subjected to strong corrosive conditions when cold, failure frequently occurred.

The change which occurs when this particular steel is heated within the above temperature range is a structural one, and it may be described for the benefit of readers who are not familiar with it. The 18-8 steel is an austenitic steel, that is, its microstructure is composed of austenite, a solid solution of iron and carbon. Austenite is non-magnetic and unstable in low carbon steel except at temperatures above 1750° F., that is to say, it exists only when the steel is maintained at high temperatures, and as soon as cooling takes place this austenite breaks up or "dissociates" into two constituents, iron carbide and ferrite. When certain elements are added to the iron-carbon alloy, the stability of austenite is considerably increased, as for example when chromium and nickel are added to the extent of 18 and 8% respectively. The resulting austenite is then rendered stable enough so that, if the alloy is cooled rapidly, the austenite persists to ordinary temperatures, but if cooled slowly or heated to a temperature within the range of 800 to 1500° F. dissociation will take place, and the carbide will be precipitated, usually at the grain boundaries. (When this takes place subsequent heating to a temperature above the dissociation temperature followed by rapid cooling will again render the alloy completely austenitic.)

It is this dissociation of austenite into fer-



Heated at 1550° F. for 68 Hr.
No failure after 200 hr. in Krupp reagent

Same. Then Heated at 1200° F. for 1 Hr.
Failed after 50 hr. in Krupp reagent

Austenitic Steel, "Stabilized" by Long Heating at High Temperature, Becomes Sensitive to Krupp Reagent After Short Time at Lower. Analysis: 0.10% carbon, 18.33% chromium, 7.98% nickel. Micros at 1000 diameters

rite and a carbide that causes the disease mentioned above. The extent to which dissociation occurs is governed by the time and temperature of heating, and to a limited extent by the chemical composition of the alloy. Modification of the composition only affects the time element by retarding the process of dissociation, and therefore, such modifications have a distinctly restricted value. Irrespective of composition, 18-8, when heated for a sufficient length of time within the above range, will dissociate and the disease will develop if the metal is in contact with a corrosive agent sufficiently active to produce it.

This disease has been termed "intercrystalline embrittlement," and manifests itself either by the formation of cracks along the crystal boundaries of the metal, or in severe cases by complete disintegration in which the intergranular constituent is destroyed or dissolved, and the crystals fall apart in the form of a powder. This disease rarely occurs unless the material is heated within the above range, or cooled slowly from above the range.

Unfortunately in the fabrication of many articles from this metal, it is not only necessary but highly desirable to weld, which involves heating the area contiguous to the weld to temperatures within this range. Equipment so fabricated will develop this disease when the service is such that the metal is in contact with an active corrosive medium.

The precipitation of carbide at the grain boundaries does not necessarily mean that the disease will develop in all cases. As a matter of fact this phenomenon of precipitation increases the tensile strength of the metal, and only slightly decreases its ductility and impact value. In many commercial applications the materials with which the metal is in contact are not sufficiently corrosive or sufficiently concentrated to produce the disease, and therefore in such cases the phenomenon can be disregarded. However, when the service to which the alloy is subjected is known to be of a highly corrosive nature, and particularly where experience has indicated that this disease will occur, it is necessary to anneal the welded equipment, or if this is impossible to take advantage of the limited protection which a modification of the composition will give. By suitably modifying the composition of this alloy the dissociation of the austenite will be so retarded that, in the short period occupied by the cycle of the welding operation, there will not be sufficient time to permit carbide precipitation to the extent which would induce any intercrystalline corrosion.

It was logical that the first attempt to modify the composition of this alloy would be to re-

duce the carbon content. This was done at the Krupp works in Germany, and based on certain laboratory tests it was at first recommended that in order to prevent the occurrence of this disease, especially in welded equipment which could not be annealed after welding, it was simply necessary to keep the carbon content of the alloy below 0.07%. Subsequent tests and the results of service showed, however, that even with the carbon content below 0.07% this alloy was still susceptible to carbide precipitation if held sufficiently long in the dissociation temperature range, and it was also found that if the chromium and nickel contents were rather low the alloy was as susceptible as though the carbon content were considerably higher in 18-8 with normal percentages of chromium and nickel.

Further research by a number of metallurgists indicated that this phenomenon could only be completely eliminated by reducing the carbon to less than 0.02%, but when this was done the alloy did not have the properties of an alloy of the same composition which was austenitic on account of its higher carbon content. Other modifications were recommended such as the addition of titanium, vanadium, tungsten or columbium, all of which undoubtedly sufficiently retard the dissociation, if the carbon content is kept relatively low, to permit of their safe use for many applications at normal temperatures after welding. With higher carbon content the addition of practically all of these elements is of doubtful value. It was also found that if the relationship between the carbon and iron is adjusted in a rational manner, the dissociation would be retarded to such an extent that such alloys could be welded safely.

Columbium Probably Best

Nevertheless all these modifications would ultimately dissociate if heated for sufficient time within the range of 800 to 1500° F., and in most cases the addition of elements other than chromium and nickel to accomplish retardation, seriously decreases the corrosion resistance of the metal. While there are a number of elements which if added to this alloy influence the rate of dissociation (and perhaps also the form and composition of the constituent which is precipitated at the grain boundaries) it has been the writer's experience that columbium is the only element which apparently accomplishes this purpose without seriously affecting the inherent corrosion resistance.

It must be born in mind, however, that all the conclusions which have been arrived at in connection with this phenomenon have been based on the results obtained with a certain specific accelerated test introduced by the Krupp laboratories. It consists in boiling the alloy (which has first been heated for various time periods at some temperature within the range of dissociation) in a solution containing 10% sulphuric acid and 10% copper sulphate. Under this test 18-8 will either completely disintegrate in a short period of time or lose its metallic ring, or else be unaffected — depending on its composition and time at heat.

It seems to the writer that one is not justified in accepting the results of this specialized test as a measure of what may happen in service, especially since it can be readily shown that samples which are unaffected by this particular solution will be seriously affected by other liquids, such as boiling concentrated nitric acid. It can also be shown that even the most stable alloys having an extremely low carbon content and those alloys with columbium, titanium and vanadium which have given the best results, as measured by the sulphuric copper sulphate test, will when welded show a distinct line of weakness at the area next to the weld if they are subjected to certain selective corrosive influences such as ferric chloride, and certain combinations of mixed acids.

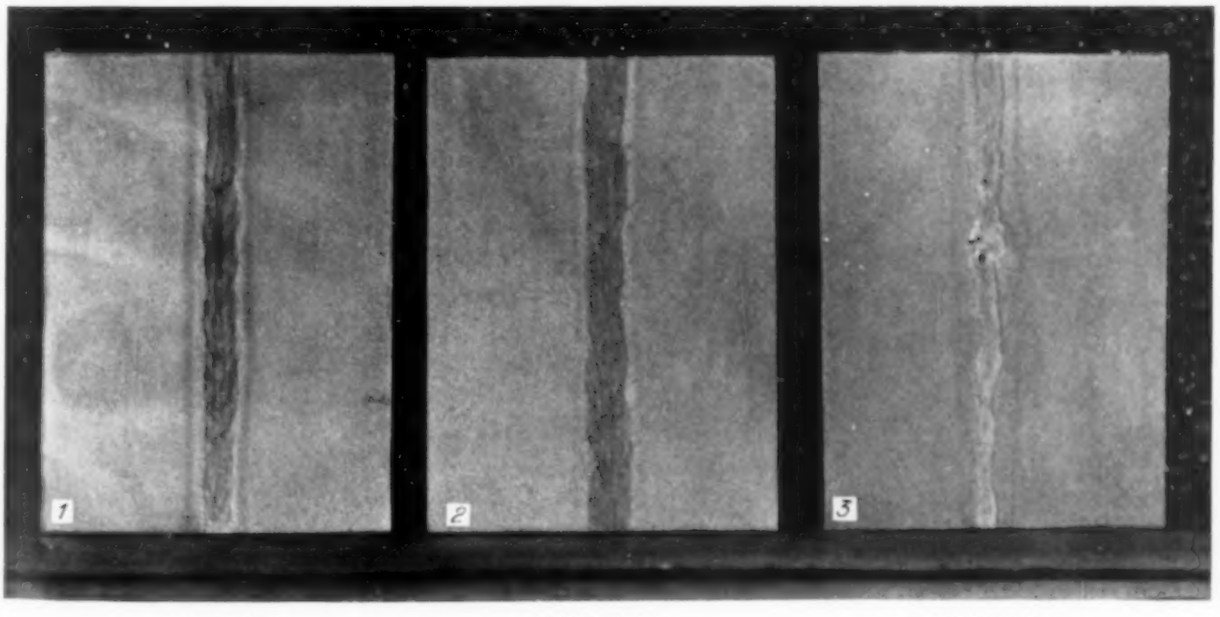
It would appear, therefore, that in spite of the results obtained by this generally accepted accelerated test adopted by the Krupp laboratories, "incipient" dissociation *does* take place when even the most stable alloy is welded and can be detected by the use of some other method of testing, and even though the presence of precipitated carbide cannot be established by the usual microscopic examination.

A careful study of the manifestions of this particular accelerated test will reveal the fact that its results are entirely due to electrolytic action brought about by differences of potential, and can be varied measurably by slight modifications in concentration, or by changes

in the composition and structure of the alloy tested. For example, if high carbon 18-8 alloy (for instance 0.12% carbon) is heated to 1200° F. for a few hours and then subjected to the Krupp test it will disintegrate very rapidly. If the same alloy is heated to 1550° F. for a short time and subjected to this same solution it is unaffected. Microscopic examination of the two samples, however, will show that the one that has been heated to the higher temperature contains a much greater amount of precipitated carbide than the one which has been heated to the lower temperature. Similarly if we prolong the time of heating at 1200° F. to 400 or 500 hr. the sample may only be slightly affected by this accelerated test, and in many cases may not be affected at all. Yet the microscope will show a much greater amount of precipitated carbide in the sample which has been heated for a long time, than the one which has been heated for a short time. The first set of photomicrographs (page 36) shows this relation of amount of free carbide and time at heat in a low carbon alloy.

It would seem that under different conditions of heating the precipitated constituent is modified in some way which changes its electric potential, and a corresponding change is obtained in the results in this particular electrolyte — namely, boiling sulphuric acid and copper sulphate. It does not necessarily follow, however, that the same results will be obtained if some other electrolyte were used (and this can be readily shown) nor does it prove to a logical mind that the same results will be obtained when the metal is used for some other purpose.

As an example, it is well known that when cyanide solutions are used, the difference in potential between certain metals is not the same as when sulphate solutions are used, and in fact the relative position of several metals in the electrochemical series depends upon the nature of the electrolyte. Use is made of this fact in the separation by electrolysis of various metals in solution, and on the other hand, by the use of certain electrolytes the potential between different metals can be brought close enough together so that the metals will deposit simultaneously. Again, in the electroplating of copper on steel or iron, the difference in potential between the copper and the iron is so great in sulphate solutions that a loose, coarse deposit is



1		2		3	
0.063%	Carbon	0.075%	Carbon	0.086%	Carbon
17.10	Chromium	19.12	Chromium	17.25	Chromium
8.96	Nickel	9.17	Nickel	8.09	Nickel
0.36	Titanium			0.35	Columbium

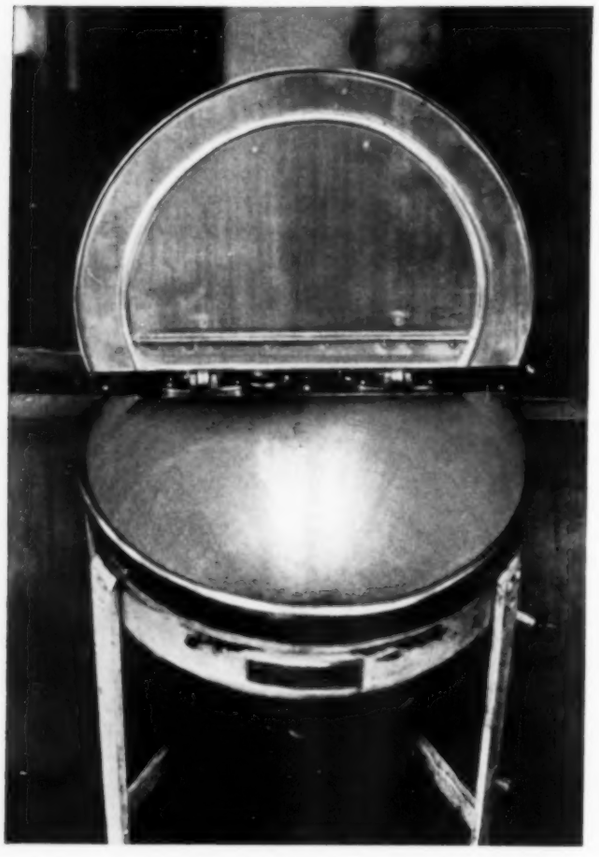
Corrodible Regions Adjacent to the Weld Appear After Immersion in Boiling Nitric Acid. All of these samples of composition noted would stand up indefinitely in the Krupp reagent without disintegration

obtained which is valueless as a plate. Cyanide solutions are invariably used to plate copper on iron or steel because the difference in potential is much less than in sulphate solutions and a fine, adherent deposit is obtained.

Therefore, one cannot expect to find that the corrosive influence of beer would be parallel to that of the so-called Krupp reagent. Why, then, should one use the results obtained by this reagent to forecast what will happen to a welded beer barrel?

An amusing incident recently occurred to the writer which illustrates this point. A "high powered" tire salesman demonstrated that the fiber which was woven in his tire when immersed in a concentrated sulphuric acid was not affected, while the fiber in his competitor's tire was destroyed. This appeared to him a very convincing reason for purchasing his tire, and he became very indignant when the writer pointed out that he was not in the habit of driving his automobile through a stream of sulphuric acid, and therefore, could see no advantage in purchasing that particular brand of tire, unless this property of the fiber would be reflected in better service.

It must therefore be recognized that the results of the Krupp test can only be used as a relative indication of the extent to which a change has occurred in the structure of the alloy, which may or may not affect its ultimate value in service, and the results must only be considered from a standpoint of relativity. It might also be said that one is able to measure with this test certain changes of high magnitude in the structure of the metal brought about by time and temperature, but one is not able to measure changes of low magnitude brought about by the same condition. As measured by the Krupp test the change which occurs by heating 18-8 to 1200° F. for a relatively short time, say one hour, is of a much higher magnitude than the change which occurs when the same alloy is heated to the same temperature for a period of 1000 hr.



Steam Jacketed Kettle Made of High Carbon 18-8. Four oxy-acetylene welded joints make up the hemisphere, which was not annealed. In perfect shape after two years service for making preserves with boiling vinegar and salt solutions. This kettle would disintegrate in ten minutes in the Krupp reagent

Short Heating Vs. Long Heating

It really does not matter what theory we adopt to explain the difference that exists; the fact remains that this test will identify the change which has occurred in one case, and fail to identify it in the other. If, therefore, the service to which the alloy is to be put involves *prolonged* heating within the range of dissociation, one is not warranted in using the results of this test to forecast what will happen in service, even if the conditions are almost identical, because as shown above the results are contradictory under varied conditions of time and temperature. It would be still more ridiculous to accept the results of this test as indicative of what will happen in service which involves corrosive influences which are not analogous to that of the solution of sulphuric acid and copper sulphate.

On the other hand, if we use this test to determine whether the short cycle of heating which takes place in *(Continued on p. 60)*

Assembly Floor, Where Standard Subdivisions Are Bolted Together Into Complete Planes, Minus Wings

ALL-METAL PLANES

for coast-to-coast transport

By R. E. Johnson United Air Lines Chicago

PROMINENTLY displayed in the modernistic dome of the Travel and Transport Building at the Century of Progress Exposition in Chicago are two aircraft. One is an odd appearing flying machine of early 1908; a biplane with wings of wood and fabric and with an uncovered skeleton fuselage structure of wood and wire. The other is the newest airliner, one of the 1933 Boeing transports, all metal, fifty of which have recently been placed in service by United Air Lines.

The new transport is as modern in appearance as the exhibition building in which it is housed, being a low-wing, all-metal monoplane with landing gear retracted into the wings, and with exterior fairing of duralumin sheet, anodically treated. The plane is entirely of metal except for a small amount of plywood used in insulating the cabin. The planes are equipped with two 550-hp. Pratt & Whitney Wasp engines, supercharged for sea level performance at 5000 ft. altitude, and have a cruising speed of 171 miles an hour with full load of ten passengers, crew of two pilots and stewardess, and a mail-express cargo. Maximum speed is 182 miles per hour, service ceiling is 18,400 ft., and absolute ceiling is 20,500 ft.

The fleet of 50 new transports was built to order in the Seattle plant of the Boeing company and marks the adoption of all-metal construction. This is especially significant, because United Air Lines operate what has aptly been called the "world's largest airplane laboratory," where is found almost every type of operating

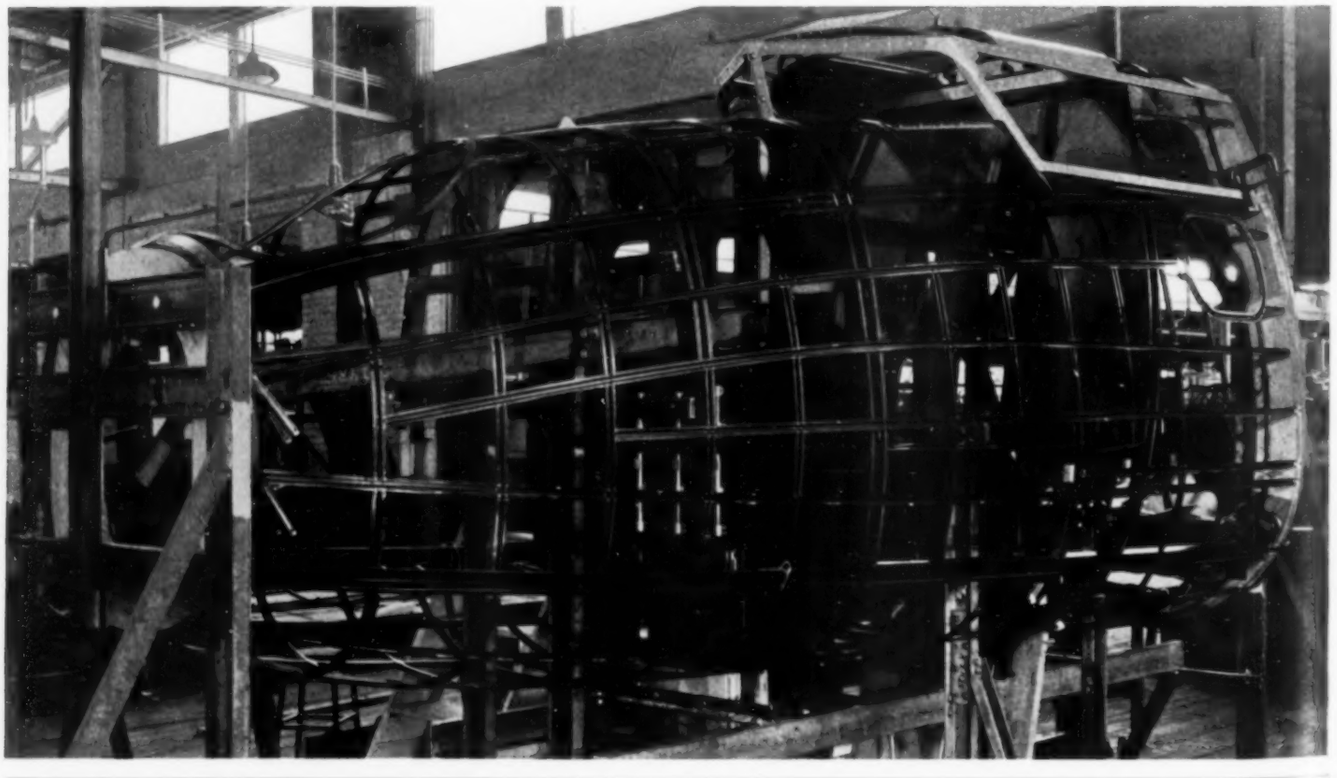
condition encountered in the country. Extremes of altitude, terrain, and weather made it imperative that aircraft employed for operations over the coast-to-coast route have a maximum of durability and strength. Flight elevations range from sea level to 10,000 and even 12,000 ft., temperatures vary from 40° below zero over the mountains in winter to 120° above on the western desert in summer. Maximum of reliability and minimum of repairs during operation and at periodic overhauls is another desirable feature insured by all-metal construction.

High strength factors are an outstanding feature of the construction. Wing spread is 74 ft., and each cantilever wing is in three sections, the one next the fuselage (housing the engine and landing gear), the wing proper or outboard panel, and the tip. The wing proper consists of spars and ribs of square and rectangular duralumin tubing covered with smooth sheet duralumin for a "skin," riveted on. For the inboard section of the wing, spars of chromium-molybdenum steel tubing are used instead of duralumin. The fuselage frame is made up of duralumin longerons and duralumin skin-stiffeners, both of U section with the top of each leg turned outward (for riveting flange). The frame is then covered with a smooth duralumin sheet, riveted on. Tail surfaces are cantilever duralumin structures, consisting of front and rear spars braced with duralumin ribs, likewise covered with smooth sheet of the same heat treated light alloy.

Duralumin is by far the most important material entering into the construction of the new transports. Bronze is employed for certain bushings; chromium-molybdenum steel tubing is used for landing gears, engine mounts, wing terminals, and tail wheels. All alloy steel is cadmium plated for protection against rust. Stainless steel is used for exhaust stacks and bearings, and pure aluminum sheet is used for fuel tanks. (These tanks, by the way, are housed inside the wing structure, near the attachment to the body of the plane. They carry a total of 272 gal. of gasoline, which permits a cruising range of 660 miles.)

All parts constructed of duralumin, including sheathing and bulkheads, are heat treated in the conventional way before forming. After aging the normal tensile strength is increased from the original 26,000 lb. per sq.in. to about 55,000 lb. As a result of the high strength-weight factors of the materials of construction, the wing of the transport is designed to bear up under a load of 36.5 tons, although the plane it-

Skeleton of Nose Section of All-Metal Plane Assembled in Jig to Insure Interchangeability With Any Other Nose Section in the 50 Transport Planes



self has a gross weight of but 6.5 tons. Strength in the landing gear of the transport is also a highly essential safety feature, and the retractable landing wheels are designed to withstand an impact of as great as 32.2 tons. The chromium-molybdenum steel skeletons are welded assemblies, and were raised from a normal tensile strength of about 90,000 lb. per sq.in. to about 180,000 lb. per sq.in. by heat treating in an electric furnace at 1625° F., quenching in oil, and drawing back at 800° F. Nickel steel, employed for terminals, bolts, trunions, and certain forgings, is heat treated to as high as 200,000 lb. per sq.in.

The adoption of a standard all-metal plane by United Air Lines resulted in new factory methods at the Boeing Airplane Co. All main parts of the transport are made in self-contained units and are fully interchangeable with corresponding parts of any other ship. Included are such items as body sections, wing sections, doors, floors, windows, engine mounts, landing gears, and so on. Careful preliminary engineering and tooling made possible this feature, which is of large importance from the viewpoint of air transport operation. Elaborate sets of jigs, dies, patterns, templets, and fixtures were constructed which not only insure interchangeability but permitted large savings in time and labor as well. Whereas welding and riveting are the preferred methods of joining the sub-assemblies of all these units, the joints between interchangeable units are bolted.

Strong Duralumin Sheet, Anodic Treated, Gives Clean Stream Lines. Neat fairing of wing into body structure also reduces drag

With such a system of construction, sheet metal work has reached a new degree of importance on almost every part of the plane. Flat sheet is handled by the bench shop; the control surface shop is occupied with such items as elevators, rudders, stabilizers, and ailerons; the wing shop fabricates structural shapes from strip and takes care of all wing construction, regardless of the type; the body shop constructs and assembles all body sections; the welding shop performs all welding and certain riveting operations; the finishing shop applies primer and finishes as well as handling the cadmium plating and anodic processes; the wood shop turns out dies, jigs, templets, and patterns; and the cable shop fabricates steel control cables as well as installing the electric wiring. Parts from all these divisions of the factory come together in the final assembly floor where the plane takes form.

In the construction of the earlier type of aircraft, which were built of wood and fabric, or with wood wings fabric covered, or steel fuselage fabric covered, the amount of skilled handwork involved is very high. This was especially evident in War times, when demand was far greater than the industry could supply. With the introduction of metal, however, the production of parts by machinery has been increased substantially, with a corresponding decrease in the amount of handwork, and consequently a lowering in the cost of production. Thus the output of commercial, Army and Navy planes can be systematized and in an emergency can easily attain hitherto unknown numbers.

By C. L. West
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Electric Furnace Co.
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COPPER BRAZING

strong, light joints made in furnace

REDUCED manufacturing costs and improved quality of product have been a common objective during the past three years. A most conspicuous aid in reaching this goal has been the recent developments in the art of joining two or more parts. When "100% joints" are really achieved, a related practice is obvious: Make intricate pieces in the form of many simple units, and join them rigidly together.

The present article will describe briefly how this is done by means of a comparatively new method of doing the old brazing operation. Brazing formerly was thought of as a low temperature welding operation (or a high temperature "hard-soldering" operation) requiring a welding blowpipe. A second variety uses a pot of molten brass. The modern operation passes the assembly through a continuous furnace containing a protective atmosphere. This is not a new idea, but in the past the cost of the necessary atmosphere has been so high that the applications have been limited; recently means for making quite inexpensive gas mixtures have been developed. The economic field is therefore widened very materially.

Brazing in controlled atmosphere is probably the only method which does not compromise the assembly either on the basis of cost or strength. Joining of steel parts — such as stampings, forgings, and screw machine parts — is accomplished by heating the assembly somewhat beyond the melting point of the brazing medium used, in a reducing atmosphere and then cooling in the same atmosphere to a temperature at which the metal will not oxidize in air upon removal from the cooling chamber. The brazing material is placed, in some convenient form as wire, powder, or granule, at or near the joint to be made, and upon melting spreads itself over the clean, deoxidized surface and is pulled into all joints by capillary action.

J. F. Schrumn described the operation as applied to jewelry and novelties made of semi-precious metals in METAL PROGRESS, October, 1931. A partial list of more prosaic parts which are now being furnace brazed includes automotive pulleys, mufflers, refrigerator parts (such as evaporators, condensers, absorbers, receivers, cover plate assemblies for brine tanks, floats, filters, and check valves), radiator cores, golf club shafts, and tennis racket frames. These assemblies are usually steel stampings and screw machine parts.

Brazing materials include silver solders, brass alloys, and copper.

Silver solders are favored for their free flowing characteristics at the low melting temperature of 1250 to 1600° F., for parts where

light color or corrosion resistance is an important item, and where higher temperatures would be detrimental to the parts forming the brazed assembly (cause grain growth, for instance). Generally speaking, the silver solders are silver-zinc-copper alloys, and the melting point goes up with the percentage of copper. They form a very strong, malleable bond between metallic parts. The material is furnished in wire or thin ribbon at a cost which varies with the market price of silver, the content of the alloy, and the shape and amount ordered, and (based on silver at 30¢ a troy ounce) will run from 20¢ to 75¢ a troy ounce. Its use must therefore be carefully economized by close fitting in the assemblies.

Brass wires and powders of various analyses, primarily copper and zinc, are used very extensively where a very strong bond between the parts of the assembly is the prime consideration, such as in the mass production of steel barrels and tanks, bicycle frames, and all articles of copper. The resultant joints are found to have all the normal strength of mild steel. The brazing materials have a melting point of 1450 to 1625° F., depending on composition, and therefore the brazing operation is accomplished at a temperature of about 1740° F. Where brass powder is used, the brazing temperature must approach 2000° F., because zinc vaporizes from the powder at elevated temperatures, and the copper-zinc residue becomes less fusible by the time the steel parts finally reach the brazing temperature.

Brass alloys are much cheaper than silver solders. Price varies with the granulation, composition, and quantity, but based on 7¢ copper, will vary from 14¢ to 27¢ per pound in sizable lots.

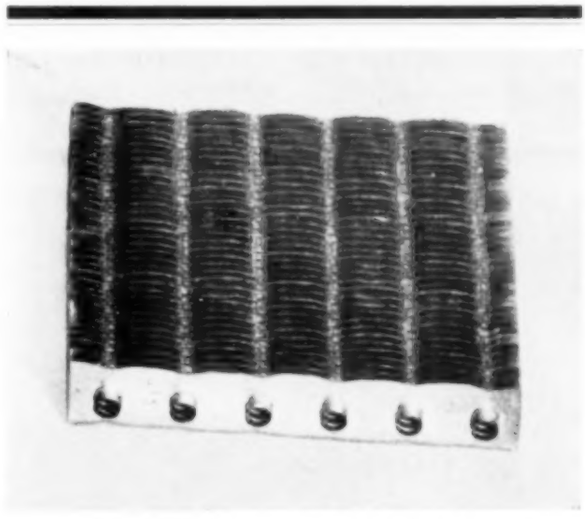
Brass alloys are not always satisfactory for some brazing operations, such as refrigerator parts subjected to relatively high internal pressures. Failure is probably due to the fact that such brass alloys give off zinc up to the time of solidification, with the result that minute pores sometimes exist in the film of alloy left in the joints after brazing. For this reason, pure copper would then be used for the brazing material.

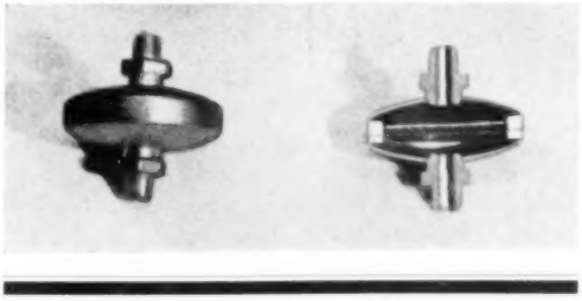
Pure copper offers the best brazing medium where strong and tight bonding of steel parts is essential. It is used as wire, ribbon, and powder; its melting temperature is 1980° F. in any form. One disadvantage is that the operation is carried out at approximately 2040° F., which naturally tends to increase the maintenance charges for the furnace.

With copper costing 7¢ per lb., the wire would come at 10¢ and the powder at approximately 16¢ per pound, in large lots.

Parts which are to form an assembly should be fabricated so that the joints to be brazed fit closely. Light press fits are very desirable; even extremely tight fits will not prevent brazing but rather will be an aid, since capillary attraction plays a very important part in the brazing operation and hence the molten metal will flow further. On the other hand, void spots or gaps in any assembly are always difficult and many times impossible to seal with the amount of copper provided.

All parts to be





Any Number of Parts May Be Joined in One Furnace Operation. Above is a condenser made of a stack of cupped pieces of steel strip; below is an oil filter made of nine stampings, screens, screw machine parts and steel washers

brazed should also be clean of heavy scale or oil deposits. The reducing action of the gas atmosphere used in these furnaces will normally clean the parts of light oxides or oil and soot films. On the other hand, a heavy scale, even if thoroughly reduced to metal in the furnace, is converted into a layer of very absorbent iron, and the possibility that molten copper can penetrate this spongy surface and bond with the solid steel beneath is doubtful, to say the least, even if a large excess is provided. Any heavy oil or grease deposits are likely to leave a deposit of carbon — an enemy of good brazing.

Furnaces of quite simple design have been installed for this operation. Up to 1800° F., one utilizing a belt conveyor of heat resisting alloy is common. When the brazing temperatures are as high as 2040° F. we have usually installed pusher types of furnaces, in which the work is carried on light shoes or trays.

In any case, equipment consists of a heating chamber in which the work is heated to the desired brazing temperature. A cooling chamber is attached through which the work emerges. The cooling chamber usually has a double steel shell, the inner chamber being filled with the protective gas atmosphere, and water is circulated between the inner and outer shells to force the cooling.

Until very recently hydrogen gas with sizable amounts of inert nitrogen was used almost exclusively for the reducing atmosphere. It very satisfactorily cleans the steel of oxide films (thus performing the function of the brazing flux) but is a serious decarburizer of steels at elevated temperatures. It is also expensive. Depending upon design, a small furnace might require from 300 to 500 cu.ft. of gas per hr., with the result that the design of entrance and exit openings may become quite complicated in order to avoid much wasteful leakage.

One of the important recent contributions to the art of brazing has been our development of low cost gas atmosphere in a small gas producer, at a cost of 20¢ to 30¢ per M.cu.ft. Such a cheap gas can be used somewhat more extravagantly, and we find that the furnace equipment can be of very simple character, which results in lower first cost and lowered operating and maintenance charges.

To illustrate the operation let us assume that we have a continuous belt conveyor type

Pulley Wheel for Automobile Fan. Old design at left used a steel hub with wide flange, and the sheet metal web was spot welded to the flange. Service failures would occur in the coarse-grained metal surrounding welds. New design alongside uses the steel hub shown in front, copper brazed to the sheet steel web at the narrow shoulder. Tested to destruction the joint holds fast and sheet steel web tears, as shown opposite

of electric furnace with reducing gas atmosphere and the problem involved is to braze a hub and pulley assembly, such as shown on the opposite page and used for an automobile fan. In the present most economical design the hub is made from steel bars on a screw machine and the web and groove is a single steel stamping.

These two parts are assembled with a light press fit as shown at the right in the view. A single strand or ring of 20-g. brass wire is then placed around the hub adjacent to the shoulder. The assembly goes to the moving conveyor belt and is conveyed into the furnace at a temperature of 1740° F.

At approximately three-fourths through the furnace the steel parts reach temperature and the brass alloy is then in a very liquid state, spreading over the metal surface in its vicinity. Most of the molten metal is drawn through the joint between the pulley and the hub and further forced out under the flange by capillary action, thus wetting the entire surfaces in contact. Any surplus forms a fillet at each end of the joint. The work then moves into the cooling hood, and the film of iron and copper alloy in the joint solidifies. After cooling to approximately 250° F. the job is removed complete.

The above-mentioned design is the result of an evolution at Spun Steel Corp. of Canton, Ohio. The immediately preceding plan had been to prepare a hub with an outstanding disk about three times the diameter (as shown on the left-hand pulley in the view) and join the steel stamping to this disk by projection welding at four points. A number of failures occurred in service by a crack in the coarse-grained metal immediately around the spot welds, possibly due to fatigue failure from vibration at high operating speeds.

Since the brazed pulleys are uniformly heated all over to a normalizing temperature of 1740° F., the strains due to localized heating at spot welds are avoided — indeed all cold working strains from drawing, punching, and spinning operations are relieved at the same time that brazing is done.

The cost of projection welding is slightly cheaper than the brazing operation, but irrespective of the improvement in quality, a final economy is found in the average pulley assembly due to the fact that the hubs can be produced from very much smaller stock than could the old types of assembly.

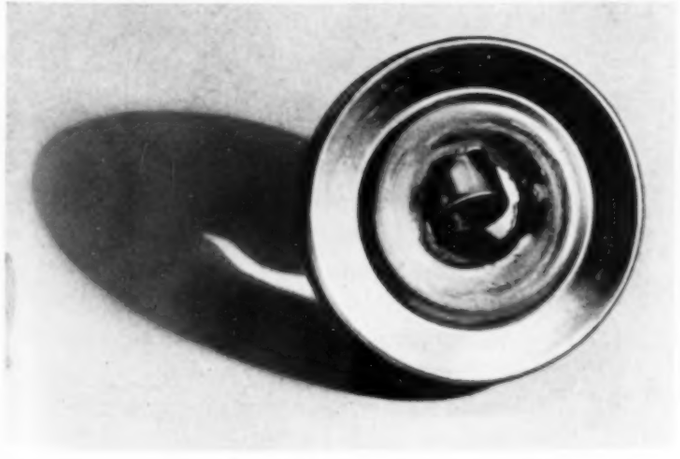
As to strength, the half-tone on page 47 shows the results of a torsion test. The brazed joint proved even stronger than the steel web, which tore apart while the brazed joint held securely.

Further reports from the laboratory of one of the leading automobile companies indicate that none of the brazed pulleys installed on cars have failed, whereas some troubles were had with the ones joined by projection welding. "In a torsion test, a load of 5160 ft-lb. was applied and weld still held, the $\frac{3}{4}$-in. diameter shaft failing. The pulley was then held on outside of hub and a twist of 7190 ft-lb. applied; the weld again held, the bolts on driver shearing. The test was discontinued, since it was the opinion that the weld had a satisfactory safety factor under the actual working load."

The area of the brazed joint in these pulleys was only 0.77 sq.in.; the flange of the hub being $1\frac{1}{2}$ in. diameter, only 0.25 in. larger than the pierced hole in the pulley web.

Some notes on other commercial operations may be of interest.

Outer parts of tennis racket frames, made by the Dayton Racket Co., are of 24-g. sheet and the inner part is 26-g., both of S.A.E. 4130 steel. The parts are assembled with a strand



of 24-g. brass wire included in the joints and brazed at a temperature of 1740° F. in an electric furnace, then reheated to 1575° F., quenched in water (or quenched direct from the brazing furnace after the metal frames in the cooling chamber had dropped to 1575) and drawn at 600° F. This gives a light frame with the necessary strength and stiffness and with proper distribution of weight. It should be particularly noted that the brazed joint is made at a temperature high enough so it is unharmed by this heat treatment.

Many Joints Made at Once

Oil filters, shown entire and in section in the bottom picture on page 45, are made of nine separate parts joined in a single brazing operation — two stampings for outer shell, two screens, three washers, and a pipe fitting for each end. The parts fit snugly together and a small amount of copper paint is applied to the joints. (Copper paint is powdered copper in a volatile vehicle.) The carrier is an alloy plate to which are welded short pieces of wire for pins to project into the lower fitting. A continuous electric brazing furnace at 2040° F. unites them into completely joined and sealed units, capable of withstanding upwards of 1000 lb. per sq.in. pressure.

Floats are being made of brass shells and assembled with a strand of 24-g. silver solder wire at the junction. Another simple method is to use 0.015-in. copper-coated steel sheet, and utilize the copper coating for making the necessary alloy at the joint.

The condenser core shown in the top view on page 45 was made of a number of stampings from 0.008x1-in. steel strip. Each piece was cupped with a slight taper, so a great many strips or laminations may be stacked to form the desired height, and lightly pressed together. The cupped portions form a number of tubes through the assembly, and a single strand of 20-g. copper wire is placed in each tube. The wire

flushes as the assembly reaches furnace temperature, and the liquid copper is drawn around each of the several hundred joints by capillary force, and the core becomes a completely sealed unit.

Mufflers are also complicated pieces made up of five or six pieces of copper-coated steel or cold rolled sheet. The shell may be either lock-seamed or lap-seamed and temporarily spot welded in three or four places. The vanes or internal parts are then pressed into the shell. If plain cold rolled steel is used, the inside is sprayed with a paint made of copper, lacquer, and lacquer thinner, and the assembly emerges from the furnace with all parts completely joined into a unit with a film of copper alloyed over the entire surface.

Golf shafts are made of high carbon steel strip spirally wound into a tube and silver soldered between laminations at approximately 1600° F. They are then reheated for hardening in a protective gas atmosphere and quenched from 1475° F. in oil, then drawn in protective gas atmosphere at 600° F.

Conclusion

It is hoped that the above will indicate the advantages which may be had from brazing in a continuous furnace heated electrically and with a controlled and reducing atmosphere.

Labor is reduced to a minimum, and the assembly has no locked-up internal stresses due to tight mechanical fit or the differential heating of welding. Joints made with copper or silver are strong, ductile, and tight against high pressure. The entire surface may be rust proofed by a thin copper film at the same time the joint is made, and any subsequent heat treatment will not impair the joint. No limit need be placed to the number of joints that are made during one trip through the furnace, and the equipment can be placed in the production line without the least difficulty.

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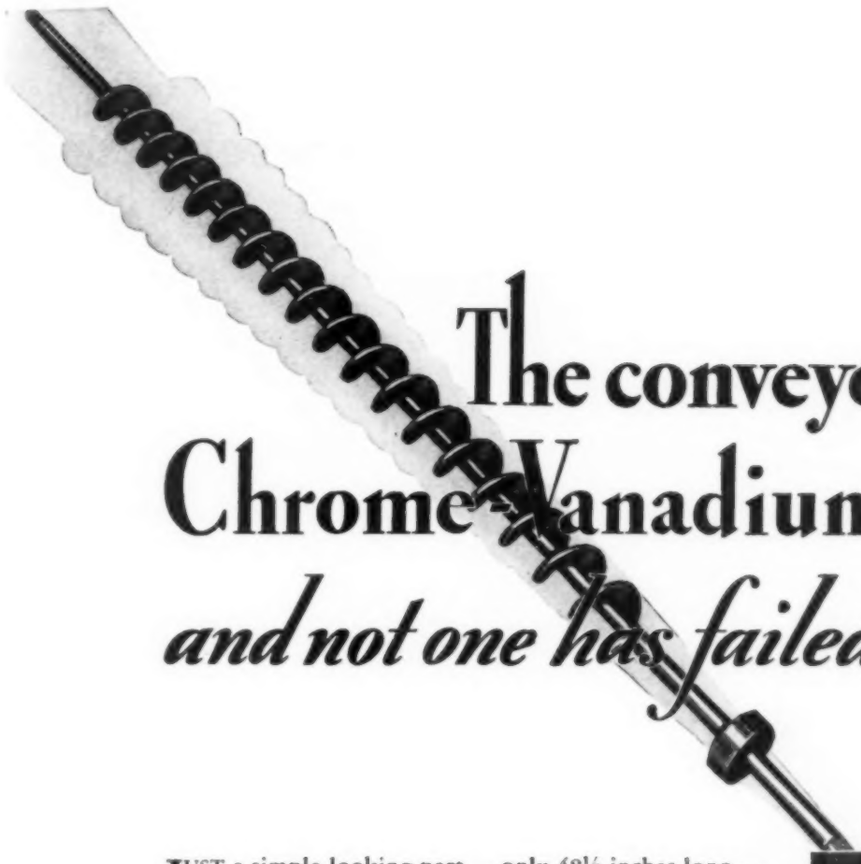
Concentrates from the literature

AN aluminum-chromium cast iron, similar in analysis to a nitralloy steel, has been developed in England for nitrogen hardening and is described by J. E. Hurst in *Iron Age* for May 18. **NITRICASTIRON**, as it is known, is air hardening and for good machinability should be annealed at 950° C. and slowly cooled. Between rough and finish machining it may be oil hardened at 870° C. and tempered slowly at 600° C. to remove internal stress and minimize distortion. Nitriding procedure is the same as for steels. Tests made with a Firth diamond indenter showed hardness of 894 and 904 for nitrided iron, sand cast, and 962 and 982 for iron centrifugally cast, as compared with 1066 for nitrided steel. Tensile strength was also somewhat lower for sand castings than for centrifugal. The nitride case is found to be coherent and free from flaking and spalling. The material is particularly applicable to cylinders and cylinder liners, as well as other engine parts requiring resistance to wear and corrosion; some liners of this sort have been in service two years and are showing excellent results.

LARGE forgings require a steel that will harden to a greater depth than is necessary for small sections. An alloy containing chromium, nickel, and molybdenum is found to be admirably suited to this purpose; it has high physical properties, hardens uniformly through a wide temperature range, can be drawn at a high temperature with little loss of strength, is free from temper brittleness, and is relatively easy and cheap to manufacture. Four types of this **FORGING STEEL** are described by M. R. Chase in *Steel*, May 15 and 22. The first type contains 0.30 to 0.35% C, 0.75% Cr, 1.50% Ni, and 0.25% Mo, and should be oil or water quenched; it is designed for shafting, piston rods and other smaller sections where good torsional strength and minimum distortion in heat treating after machining are required. Type 2 is the same with higher carbon (0.35 to 0.45%). It gives slightly higher properties in medium sections and can be normalized and drawn where quenching is not practicable. Type 3, with 0.50 to 0.60% C and 0.30% Mo, is for oil-quenching. It is semi air-hardening and finds its widest application in drop hammer die blocks because of its inherent toughness and balanced hardening characteristics. Type 4 has 0.50 to 0.60% C, 0.80% Cr, and 0.75% Mo, and is fully air-hardening. It is exceptionally resistant to heat checking and its applications are specialty dies, inserts, and forging tools.

EFFECT of titanium on cast iron is to increase strength by producing fine graphite particles, but this is somewhat neutralized by its graphitizing tendency, which appears when an excess is present and which results in a larger proportion of ferrite in the structure. G. F. Comstock, in *Iron Age*, June 1 and June 8, reports results of practical tests showing the best strengthening effect in small ladles of iron with addition of two parts per 100 of a ferrotitanium containing 15 to 20% Ti. In larger melts only about half as much of the ferro-alloy is required. Ferrite formation can be minimized in **TITANIUM CAST IRONS** by the use of chromium as a carbide former; the structure is then a fine, sorbitic pearlite. Thus, a 0.50 to 0.70% Cr, 0.1% Ti iron was equal in strength and superior in machinability to molybdenum irons, and superior in both strength and machinability to chromium-nickel cast irons. Fractures of chill-test castings were dark and fine, and indicated that titanium has as much effect as nickel in counteracting the tendency of chromium to make the iron white. Cost is also considerably lower.



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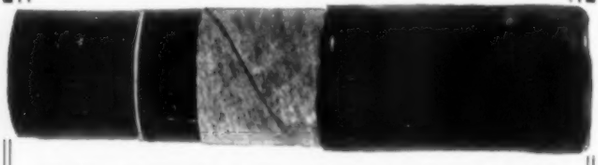

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AN overnight endurance test based on the assumption that, below the endurance limit, strength of metal subjected to repeated stress will increase because of cold work, but above the endurance limit it will decrease because of fatigue cracks and damage, is detailed in a paper presented by H. F. Moore and H. B. Wishart to the American Society for Testing Materials meeting last month. Several specimens of the material are subjected to 1,400,000 cycles of different stresses above and below the estimated **ENDURANCE** limit. (On a rotating beam machine running at 1500 r.p.m. this required 15½ hr.) Tensile strength of each specimen is then determined and plotted against the stress to which it was subjected; the stress corresponding to the maximum tensile strength on this curve is then compared to the endurance limit determined by more conventional methods. Both overnight and long-time fatigue tests were made on brass, monel metal, duralumin, and five types of steel, and for all except brass the overnight value was slightly lower, thus being on the safe side; difference from the long-time value ranged from 0 for monel to 11.8% for duralumin.

STUDIES on leaded bearing bronzes by H. K. Herschman and J. L. Basil (reported in Bureau of Standards *Journal of Research* for May) have lead to the development of an alloy containing up to 45% lead, in which the tin or antimony, ordinarily added to disperse and distribute the lead evenly, have been replaced by 0.4% sulphur and 1.5% silicon-zirconium alloy (Zr 55%, Si 38%, Fe 5%, traces of Al and C). Wear resistance of these **BEARING BRONZES** was found to be equal or superior to that of the commercial alloys, compression strength was as high, impact strength a little lower (although the difference decreased with increase of testing temperature) and resistance to deformation by pounding was not materially affected by temperature. Experimental bearings showed excellent lead distribution in continuous copper matrix; some bearings for connecting rods, how-

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ever, were streaked with lead segregations thought to be due to some factor in the manufacturing process. These failed in a test run in an airplane engine, but the main bearings appeared to be in the same condition as ordinary copper-lead bearings after 68½ hr. service.

SOME manufacturers believe that a stress relieving anneal must go above the critical range, but Jules Muller in the American Welding Society *Journal* for April presents data showing considerable deformation or "creep" in a 0.20 to 0.30% carbon steel under a stress of 1000 lb. per sq.in. at temperatues above 700° F. Welds in pressure vessels may be stressed up to 80% of the yield point, but the curves show that a load producing even a fraction of this will cause considerable creep at 1100 to 1200° F. This relieves local stress without structural injury. This temperature is chosen for the STRESS-RELIEVING ANNEAL since the metal retains sufficient strength to carry its own weight without sagging. Stress relieving may be obtained by hydrostatic pressure sufficient to strain the material just past its yield point, but this only redistributes the stress over a larger area, whereas a low temperature anneal leaves the vessel in a strain-free condition.

EXPERIMENTAL development of cast iron crankshafts containing 3 to 4% nickel and some chromium and molybdenum brought forth the surprising fact that the endurance of this material seemed to be higher than that of steel. Tests were made by definitely offsetting the center bearing of the shafts $\frac{1}{32}$ to $\frac{1}{16}$ in. and operating to failure, as is frequently done in automotive laboratories. T. H. Wickenden, in the June issue of S.A.E. *Journal*, explains this phenomenon as the difference in sensitivity of steel and cast iron to stress localization by sudden changes in section. High stress concentrations exist at each bearing and pin in the shaft, and additional "stress raisers" caused by deflection

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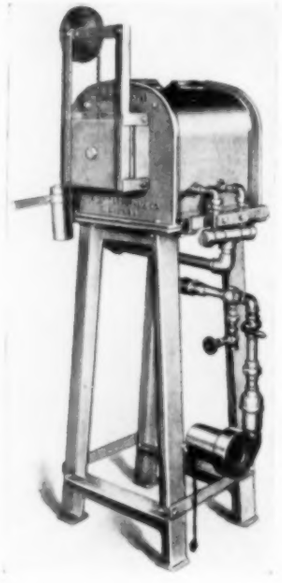

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at the center bearing are sufficient to cause rapid failure in a steel forging. **CAST IRON CRANKSHAFTS**, on the other hand, are not so sensitive, due probably to the microstructure, wherein the multitude of graphite flakes may be regarded as faults already present, and the addition of another stress raiser by faulty design has small effect.

BEILBY'S theory is commonly held, that hardening by cold work is associated with a change in a certain amount of metal from the crystalline state into an amorphous condition. If this is true, the cold worked metal would have a different quantity of internal energy than a similar volume of annealed material. To verify this assumption, Dr. Walter Rosenhain and V. H. Stott have investigated the amount of energy absorbed by aluminum and copper wire during **HEAVY DRAFTING** through a diamond die mounted in a calorimeter. Results have been published in *Proceedings* of the Royal Society, A, Vol. 140, which describes the equipment for accurately measuring the work done and the heat liberated. Total work required to draft annealed aluminum 66% (in length) is 38 joules per gram, of which 0.47 joules per gram is rendered latent in the metal. To draft annealed copper 69% requires 31 joules per gram, of which 0.96 is absorbed by the metal. This hard copper drafted a further 28% absorbed 0.12 joules per gram more; apparently the proportion of energy retained by the metal is a diminishing function of the work performed on it. These figures are of the same magnitude as those previously published by Farren and Taylor, and determined from tension tests.

SAFETY razor blades sharp on both edges are ordinarily made of 1.20 to 1.35% carbon steel strip, 0.006 in. thick. Most of it is of Swedish or German origin, as American mills do not ordinarily roll less than 0.009 in.; the

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latter is sufficient for the single-edged blades, according to Dr. R. W. Woodward in *Iron Age*, May 25. Structure at 100 diameters is fully spheroidized cementite with the fine carbide particles uniformly distributed. Heating **RAZOR BLADES** for hardening is done after blanking (the individual blades are kept in strip form by small linkages left behind) in a long tube furnace, with controlled atmosphere, and the last half carefully maintained at uniform temperature. Water-cooled quenching blocks set at the outlet door give a bright scale-free strip. These blocks may be split, so the center of the strip cools slowly, and thus is less liable to crack when flexed in the razor-blade holder. Immediately after quenching, the strand passes between hot tempering blocks. For superior cutting qualities in the finished blades this draw should be followed by a much longer one at lower temperature, either in an air furnace or oil bath.

X-RAY paper for the production of "exographs" (X-ray radiographs) has certain advantages over film. The cost is less than half; a single intensifying screen is used and two duplicate negatives can be made simultaneously; paper when developed can be examined in any light without a special viewing box; it can be reproduced by photostat; it can be developed more rapidly, is easier and safer to handle, and is equivalent to film in speed and contrast. These conclusions by Ancel St. John and H. R. Isenburger were described at the American Society for Testing Materials, Chicago meeting. Paper exographs are well suited to **X-RAY INSPECTION** of welded pressure vessels. In *Steel*, June 5, Mr. Isenburger compares the cost of inspecting a vessel 40 ft. long, 4 ft. outside diameter, with three 10-ft. longitudinal seams and four girth seams. Paper for complete inspection costs $6.00, two papers for duplicate prints cost $12.00, and film costs $16.90. Similar rates for A.S.M.E. Boiler Code inspection (¼ of each girth seam) are $3.45, $6.90, and $8.30 respectively.

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The well known rust preventive, No-Ox-Id, is now available from Dearborn Chemical Co. as a foundation for paint. It is available in the colors red, gray or black. A booklet explains how maximum resistance to corrosion can be obtained. Bulletin Ju-36.

Low Cost Recorder

Inexpensive dependability in measuring and recording temperature is the great asset of the new Leeds & Northrup round chart Micromax indicating recorder which brings the reliability and easy maintenance of the motor-driven null recorder to a new low cost. Bulletin Ap-46.

New Type Furnace

A new bell-type retort furnace made by American Gas Furnace Co. can be used in quick succession for carburizing, nitriding, bright annealing in gas atmospheres, or for hardening, normalizing, tempering or annealing. It is an ideal heat treating tool where production is widely varied in character. Bulletin Jn-11.

Titanium Cast Iron

The effects of titanium on the structure and properties of gray cast iron, especially as contrasted with those of other commonly used alloys, are described in a pamphlet offered by Titanium Alloy Mfg. Co. The results given were obtained by regular operating practice in several foundries and not solely by laboratory experiments. Bulletin Jl-90.

Furnace Heat Transfer

The practical application of the coefficient of heat transfer from furnaces to material is emphasized in a new folder of Electric Furnace Co. The folder is a reprint of two recently published technical papers which contain much valuable information for operators of electric or fuel fired furnaces. Bulletin Jn-30.

High Cr Cast Iron

A pamphlet describing foundry production of cast irons containing from 15 to 30% of chromium has been issued by Electro Metallurgical Co. These cast irons do not grow or scale after repeated heatings and are excellent for high temperature work. Bulletin Ma-16.

Welding Stainless

An unusual amount of practical data is contained in a fine booklet just put out by Republic Steel Corp. which gives recommendations for welding the several Enduro stainless alloys. Generously illustrated. Bulletin Jn-8.

Nitriding Facts

Information on possible new applications of Nitralloy and the nitriding process in view of recent developments may be obtained from Ludlum Steel Co. New economies in production and a better product may now be obtained. Bulletin Jn-94.

New Way to Fight Rust

A new plating process for protecting steel against atmospheric corrosion is described in detail in a handbook entitled "Duozinc" issued by R. & H. Chemicals Dept. of E. I. du Pont de Nemours & Co. Besides a description of the process, the handbook gives detailed information on the most efficient electrochemical methods of curbing corrosion. Bulletin Jl-29.

Quenching Handbook

E. F. Houghton & Co. have published an excellent 80-page handbook on the subject of quenching. More than 30 charts and photomicrographs help tell the story. A copy will be sent free to those who request it. Bulletin Jl-38.

Maintenance Welding

This interesting booklet describes the use of the oxyacetylene process in the reclamation of broken and worn machine parts, alteration, fabrication and installation of equipment. Such equipment as piping, tanks, machine elements, engine and pump parts and conveying systems is covered in the 16-page illustrated booklet of Linde Air Products Co. Bulletin Jl-63.

2 Everdur Booklets

Two recent publications of American Brass Co. discuss Everdur, the high strength, corrosion resisting copper alloy. One covers its physical properties and resistance to corrosion, the other tells how to weld it. Either or both will be sent. Bulletins Jl-89a and Jl-89b.

Quicker Heat Treating

Driver-Harris Co. discusses Nichrome sheet containers for heat treating in an illustrated folder which honestly states that while for certain purposes sheet containers cannot be used economically, there are a multitude of installations where their advantages of lightness and quicker heating can be fully utilized. Bulletin Jl-19.

Welded Construction

A very enlightening publication of Bethlehem Steel Co. describes the advantages of welded construction in the fabrication of machinery parts from rolled steel shapes. The results are said to be sturdier and more economical construction.. Bulletin Jl-76.

Turbo Compressors

A series of three bulletins is available from Spencer Turbine Co. describing their Turbo Compressors for oil and gas fired equipment and foundry cupolas. Sizes range from 100 to 2,000 cu. ft., 1 to 300 h. p., 8 oz. to 5 lbs. Bulletin Fe-70.

Recuperators

The complete story of recuperators built by Carborundum Co. for industrial furnaces is told in a readable booklet. The range of types available is described and the operating conditions are outlined in a clear manner. Bulletin F-57.

X-Rays in Industry

General Electric X-Ray Corp. has available a profusely illustrated brochure entitled "Industrial Application of the X-Ray," which gives the complete story of the field of application of this modern inspection tool. Valuable information is presented. Bulletin Ma-6.

Art of Metallography

Bausch & Lomb Optical Co. offers a 130-page book, "Optical Instruments for Examining Metals," which is a beautifully executed source of information on this subject. The book is at once a convenient reference text on optics, a treatise on photomicrography and a catalog of B. & L. products. Bulletin Jn-35.

Which Cast Iron?

A novel and very valuable self-reading chart for anyone interested in cast iron has been compiled by International Nickel Co. The device recommends analysis and heat treatment and gives physical properties for cast irons suitable for 50 different applications. Bulletin My-45.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

Fatigue Testing

That much discussed topic—fatigue testing—is covered in a publication of Thompson Grinder Co. Interesting data on fatigue of metals and a description of the rotating beam type of fatigue testing machine are presented. Bulletin D-23.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

3 Handy Charts

Brown Instrument Co. has printed three handy tables on durable cardboard for use in the heat treating department or laboratory: A conversion table for the Fahrenheit and Centigrade scales, a table of melting points of chemical elements and a heat color chart showing actual colors from 900° to 2200° F. Bulletin Jn-3.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in one of that company's publications. Bulletin D-17.

Stainless Sheets

A very useful booklet describing the stainless steel sheets and light plates made by American Sheet & Tin Plate Co. gives recommendations for fabrication and a description of finishes and analyses available. Bulletin Ap-96.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is available to all those interested in the pickling of steel. It not only describes the merits of these inhibitors, but it gives a table of suggested inhibitor strengths to be used in the pickling of the various grades of steel. Bulletin Ap-95.

Closer Heat Control

Anticipatory control action may be obtained with any pyrometer controller by adding the Deoscillator developed by Foxboro Co. A new folder tells how the device prevents over-controlling by augmenting the thermocouple emf. when the temperature is low and opposing it when the temperature is high. Bulletin Ap-21.

"Vee-less" Arc Welds

New literature covering a very recent development in arc welding has been prepared by Metal & Thermit Corp. Known as Murex Straight Gap welding, the new process eliminates grooving or "veeing" the edges even of heavy plates. Welding time is halved and other savings are effected, it is claimed. Bulletin My-64.

Heat Distribution

The advantages gained by uniform temperature distribution throughout furnace charges are fully described in a publication of Westinghouse Electric & Manufacturing Co. In properly designed electric furnaces, heat can be accurately distributed and controlled, with resultant great savings in cost. Bulletin MP-5-33.

Binocular Microscope

The new series of Leitz binocular microscopes yield such an exceptionally large field that at low or medium magnifications a large object can be completely examined without moving the specimen. A pronounced stereoscopic effect is an advantage in metallographic examination. An illustrated folder gives full details. Bulletin Jl-47.

Ingots of Quality

Their new ingot stripper produces fine big-end-up ingots at lower cost than is now experienced in producing ordinary ingots of indifferent quality, says Gathmann Engineering Co. in a new booklet. Operation is economical even when the plant runs at only 10% of capacity. Bulletin Ja-13

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Corp. A list of the standard industrial type heating elements and a coordinated list of terminal mountings and accessories is included. Bulletin N-25.

Sheffield Steel

Wm. Jessop & Sons, Inc., in a recent publication explain why their Sheffield Superior oil hardening steel does not distort and is easily machined. They assign as reasons a special anneal and a proper balancing of the carbon, manganese and tungsten contents. Full details are presented in Bulletin Jn-61.

Melting Aluminum

Aluminum and white metal alloys are easily and efficiently melted in the new model AT pot furnaces made by American Electric Furnace Co. New design features make for accurate temperature control, freedom from contamination of the melt and easy pouring. A complete description is given in Bulletin Jn-2.

Resistance Wires

Every user of electric furnaces will be interested in a new 40-page booklet prepared by Hoskins Manufacturing Co., to present data on nickel-chromium wire for electrical resistance use. A valuable feature is a new table of temperature emf. values on Chromel-Alumel thermocouples as established by the Bureau of Standards. Bulletin Jn24.

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Concentrates

SINCE it is frequently necessary to make minor alterations or adjustments on die-casting dies, a material which will permit of local softening is required. How nitrided dies can be spot softened by heating them to 950 or 1000° F. and fusing weld metal into the surface is told by H. H. Ashdown in *American Machinist* for May 24. Either oxy-acetylene or electric fusion may be used; with the latter a 1000-Vickers-Brinell case may be softened in order to drill a ¼-in. hole without softening the immediately surrounding area to less than 950 Vickers. Softening will not be as localized if the gas flame is used, but this is unimportant if the tool is to be re-nitrided after machining. On edges required to resist wear or erosion, the fused welding wire may be too soft even after re-nitriding, and nitriding steel wire is used.

ONE of the recent developments of the Bureau of Standards is equipment for use at high magnetizing forces (100 to 1000 oersteds) described by R. L. Sanford and E. G. Bennett in the April issue of the *Journal of Research.* This **MAGNETIC TESTER** is designed for specimens ½ to 1½ in. wide and up to ¾ in. thick. It provides uniform magnetization and does not heat the specimen. In the March issue appears another article by Mr. Sanford on an experimental model of a magnetic balance for measuring the permeability of **AUSTENITIC STEEL**, thought to be an index of corrosion resistance. This instrument is portable and can be used on completed structures, and consists of a pair of astatic magnets clamped on a pivot with like poles together, thus neutralizing the effect of the earth's magnetic field. A phosphor bronze helical spring connects the pivoted magnet to a spindle with a graduated dial to measure the torque. To operate, the instrument is set with the hemispherical end of the magnet touching the part to be tested. The spring is twisted, and the torque just sufficient to pull the magnet away from the test piece is read on the dial — a relative value of permeability.

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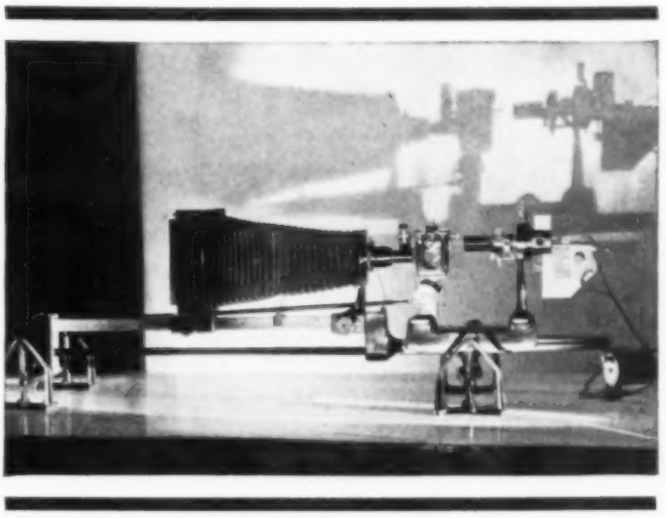

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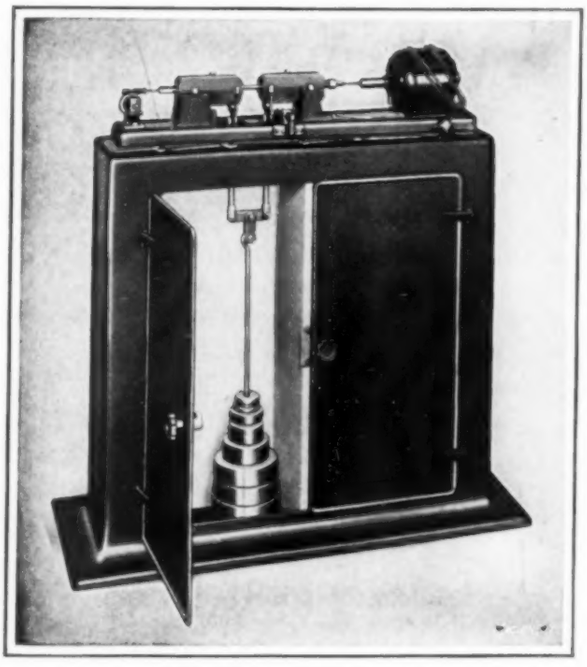

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? Krupp Test ?

(Continued from p. 40) a welding operation has produced a change in the alloy, it is quite possible to accept this manifestation as a forecast of what will happen to the alloy in service, which in the majority of cases involves a less active corrosive agent, providing the service does not also involve prolonged heating within the range of 800 to 1500° F. In other words, any 18-8 alloy (irrespective of modification in composition) which when welded and subjected to this test does not disintegrate at the area adjacent to the weld, can be considered reasonably safe for most applications. However, the results obtained by this test on material which has been subjected to long exposure to temperatures between 800 to 1500° F. should not be used to determine the influence of the tempering treatment which occurs during welding.

Modern methods of electric welding, such as line welding or high speed continuous spot welding under water, make it possible to weld 18-8 so rapidly that no tempering effect takes place. With this method of welding composition is relatively unimportant. When experience can be used as a guide, and when laboratory tests duplicating service conditions indicate, it may be found necessary to anneal even the most stable composition after welding by more conventional methods. For example, none of the so-called stable compositions, including alloys bearing titanium or columbium, and also those alloys which have been "stabilized" (a term which apparently is as descriptive as the word "permanent" in the language of a hairdresser) can be used for hot concentrated nitric acid, unless the welding operation is followed by a final anneal.

The columbium bearing alloy, which is perhaps the most stable of all as measured by the results of the Krupp reagent in conjunction with long time thermal exposures, will show at the area adjacent to the weld a loss 5 to 10 times higher than that which is shown on the original material in hot concentrated nitric acid.

(Continued on page 62)

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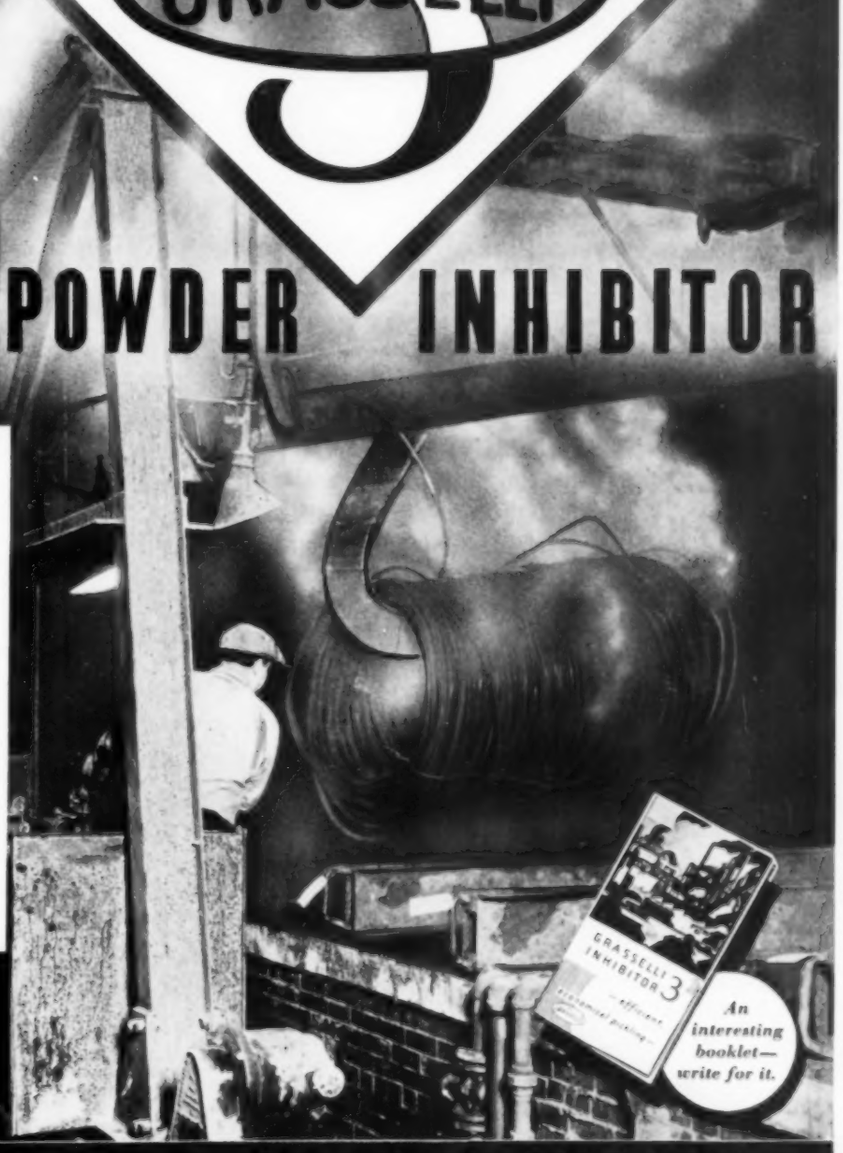

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? Krupp Test ?

In conclusion, the writer wishes to point out that the results obtained by the Krupp test can be used to great advantage in conjunction with service experience in predicting what may occur to welded equipment in service (particularly when the service is at normal temperatures) when the test has been made on samples which have been subjected for a short time only to temperatures in the carbide dissociation range. Even under these conditions it must not be assumed, because failure does not occur in this reagent, that no *dissociation* has resulted, because in many cases other active corroding agents show a distinct line of attack adjacent to the weld. (See the sample joints on page 39.) The amount of dissociation, however, may not be great enough to prove harmful with less active corroding agents.

When however, we are dealing with high-temperature service in the dissociation range under corrosive conditions, where the time of exposure is very long, then the results of the tests in sulphuric acid and copper sulphate become of very doubtful value. Differences in potential in the various parts of the alloy are then entirely eliminated, or so reduced that the Krupp reagent fails to produce disintegration, yet it is no criterion that intercrystalline corrosion will not occur when 18-8 is subjected simultaneously to temperatures in the dissociation range and active corroding agents.

It is not the writer's intent to disparage any accelerated test which is intelligently applied and standardized against known service conditions, but to point out that the indiscriminate use of an accelerated test is likely to prove more harmful than beneficial. There have been thousands of welded installations particularly in the dairy, architectural, food and automobile industries, where the service has been entirely satisfactory even though the 18-8 alloy would have disintegrated in the Krupp reagent. It would indeed be unfortunate if the use of this test should exclude this very valuable alloy for such purposes.

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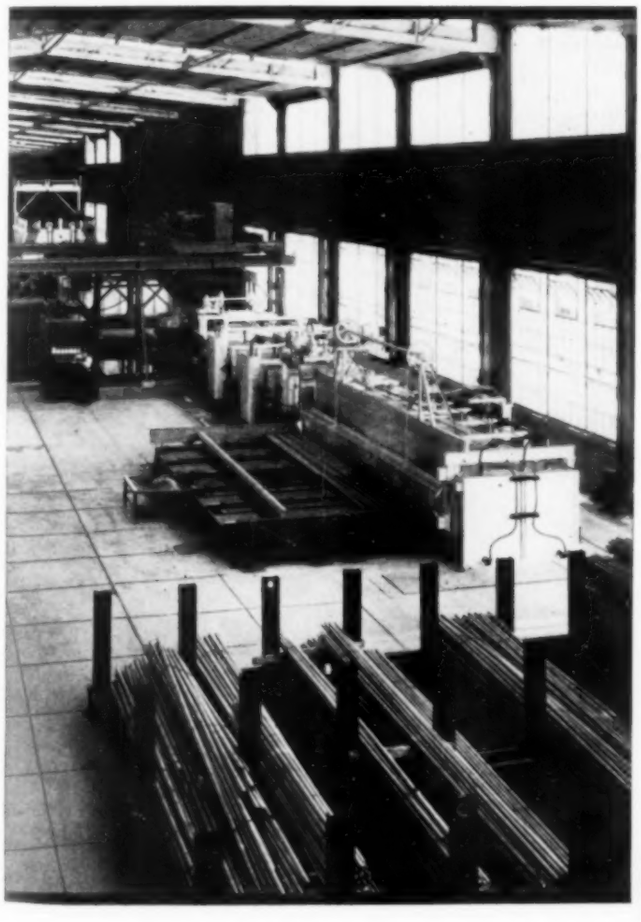

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